ANALYSIS OF AIR FORCE WARTIME CONTRACTED CONSTRUCTION PROJECT PERFORMANCE

THESIS

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Abstract

US-led construction projects in Afghanistan have performed poorly on average; indeed, it is the norm to deliver projects late to need and over budget to the customer. Using a dataset of 25 Afghan wartime projects, two separate, yet related questions relating to these DoD construction activities in the Afghan theater of operations were investigated. These questions are: 1) What factors affect the success of construction projects; and 2) How do project outcomes differ based on the contract type? First, with regards to critical success factors, current literature suggests that wartime projects may face the same cost and schedule factors as peacetime projects, with some notable additions. Using peacetime factors as a baseline, project factors, health and safety compliance, quality of work, technical performance, work productivity, and external environmental factors were tested with contingency tables to determine if they are predictive of schedule or cost performance. External environmental factors, including weather and wartime security, were not predictive of project performance. However, cost performance and schedule performance was found to be significantly dependent on government-issued excusable delays. Moreover, project management deficiencies were predictive of poor schedule performance but not cost performance. Second with regards to contract type, as the Afghan security condition was volatile, contracting officers dynamically used both reimbursable and fixed-price contracts in order to accomplish the mission. Using the Mann-Whitney tests, performance differences between contract types were explored. Reimbursable contracts were found to have significantly greater cost and

schedule growth. Additionally, fixed price projects were found to have more problems with design performance and contract management. There was no significant difference in overall project quality. In conclusion, cost monitoring from the owner and scrutiny of project management is critical to the success of reimbursable contracts, and technical performance monitoring is necessary to ensure that fixed-price projects meet deadlines.

To every construction engineer, project manager, and government representative who tries to do good when there is so much bad: This is for you. Keep fighting the good fight.

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One cannot adequately express in words just how difficult it is for a spouse to support another in the endeavor of graduate school. All I can say is that I am overwhelmingly impressed with how my wife has supported me for the last year and a half as I slogged my way through this research, spent many nights at school instead of at home, while she cared for the kids. Nevertheless, she shared countless hours with me dialoguing about this thesis: the very thing she knew was pulling me away from home. Her insight and suggestions have significantly contributed to this end-product. She deserves the diploma as much as I do.

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Ryan M. Hoff

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ANALYSIS OF AIR FORCE WARTIME CONTRACTED CONSTRUCTION PROJECT PERFORMANCE

I. Introduction

Background

Military construction is a critical support element to the establishment of a national defense system. Unfortunately, these construction projects are not immune to challenges, delays, and cost overruns, particularly in wartime construction environments. From the beginning of the nation-building effort, Afghanistan construction projects construction challenges and failure occur so frequently that they have become expectedly commonplace. Of the $100 billion allocated to the project by June 2014, $23.1 billion had been allocated for construction projects. The Departments of Defense and State have been responsible for the majority of the projects, and have most often utilized the Air Force Civil Engineer Center (AFCEC, and formerly known as the Air Force Center for Engineering and the Environment, or AFCEE) and the United States Corps of Engineers (USACE) as construction agents (Thibault, 2011). In 2007, AFCEC became a key construction agent for the NATO Training Mission in Afghanistan (NTM-A), and the program is still in operation as of March 2015. As the client and recipient for this research, they wish to gain “lessons learned” that may benefit future projects, whether in Afghanistan or a different wartime location. This introduction provides a background of the problem for investigation, explains the sponsor’s need for the research, and finishes with a brief description of the scope and methodology for the paper.

The AFCEC program, though comparatively small in number of projects when compared with USACE, comprised a significant portion of the monetary allocation for construction. The program executed nearly $3 billion in construction from 2007 to 2014. The program used a heavy equipment repair and construction (HERC) contract, which consisted of multiple pre-approved contractors. Unlike local contractors, commonly used by USACE, these HERC contractors were large construction companies with significant financial resources. The HERC contract served as a competitive indefinite delivery indefinite quantity (IDIQ) contract. The individual projects were tendered by AFCEC as task orders (although, in the remainder of this thesis, projects are also referred to as contracts). Much like USACE, the AFCEC program experienced significant challenges in cost and schedule growth, but their HERC model was also heralded as a program that had (until 2013) never terminated a contractor for default.

Thus far, there is little research that provides insight into wartime construction challenges, including Afghanistan. Two studies have been performed analyzing construction challenges in Afghanistan. The first was sponsored by USACE and performed by Affleck et al. (2011) who surveyed construction personnel on the most common challenges. The second was another AFIT thesis by Jaszkowiak (2012) which analyzed USACE and AFCEC projects to find performance differences between firm fixed price (FFP) contracts and cost-plus-fixed-fee contracts (CPFF) using some quantitative data, but primarily personnel surveys. The results of these two research projects provide some insight, but many questions remain regarding causes of poor project performance, as well as performance differences between contract types.

Therefore, AFCEC has commissioned this thesis to gain further knowledge of construction difficulties on projects in Afghanistan. This thesis seeks to build upon the two previous research efforts for a more in-depth data analysis on 25 AFCEC construction projects.

Problem Statement

It has historically been very difficult to execute construction projects in wartime environments, and Afghanistan has been no exception to this trend. The AFCEC contracting system has used both FFP and CPFF contracts to execute projects, and both contract types have experienced severe difficulties. There are many factors and root causes from from which construction challenges can originate. However, there may also be predictive performance factors that will help project managers anticipate or overcome construction challenges. Moreover, there may also be performance differences in different contract types that will provide focus areas for government officials when auditing project progress. However, there is little knowledge of what these factors are in wartime construction projects. As such, there is not a consistent framework for government managers to scrutinize contractors in order to control costs and schedule.

Research Objectives/Questions/Hypotheses

The objective of this thesis is to understand which factors may be predictive of the construction budget and schedule performance in wartime projects. Additionally, it seeks to find significant performance differences between reimbursable and fixed price contracts. There are many performance metrics, such as cost, schedule, and quality. The literature review will provide guidance for performance measures by which these

challenges and differences can be analyzed. To answer these questions, this thesis uses the following major factors: Project Factors, Health and Safety, Quality, Technical Performance, and Productivity, and External Environmental Factors in wartime construction projects. Therefore, we seek to answer the following questions in the form of two scholarly articles:

1) Which factors affect the success of wartime construction projects?

2) How do wartime project outcomes differ based on the contract type?

Scope and Methodology

The in-depth data gathering is comprised of two primary investigations for each project. The first portion analyzes the invoicing and schedule history of the project to gain a thorough understands of all cost and schedule growth. The second portion surveys the daily reports for the projects during their respective courses of construction and identifies all major deficiencies. This deficiency data will be summarized and sorted into categories. These are the factor groups by which statistical analysis of project performance can be performed.

The primary methods for statistical analysis of the data will be the contingency table (for Article 1) and the Mann-Whitney comparison of medians (for Article 2). It is not necessary to include detailed steps related to statistical methods in scholarly articles because it is assumed that readers of scholarly journals have some general understanding of the methodologies. Therefore, a slightly more detailed explanation of the methodology is contained in Chapter 5.

Significance

There is almost very little research that captures mistakes and challenges in the Iraq wartime construction effort. Unfortunately, many of the same mistakes were repeated in the Afghanistan reconstruction effort. Improved knowledge of construction performance gives government officials better tools for decision-making and negotiating with contractors. This research will ideally precede an increased effort by US government agencies to seek out root causes of construction struggles in order to improve management and oversight for future projects.

Preview

This thesis uses the scholarly article format. Chapter 2 and Chapter 3 are the articles produced from the research. They are both being prepared for submission to the following journals: *Journal of Construction Engineering Management* and *Construction Management and Economics*. The two articles will comprise the body of this thesis and contain the elements of research in the layout as per the journal submission requirements. They individually contain their own abstract, introduction, literature review, methodology, results, discussion, and conclusion. Chapter 4 contains additional discussion of the research methodology and results. Chapter 5 contains a summary of the research effort, as well as findings and future research not discussed in the bodies of the articles themselves.

II. Scholarly Article 1: The influence of project and performance factors on construction performance: A wartime perspective

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Abstract

US-led construction projects in Afghanistan have performed poorly on-average; indeed, it is the norm to deliver projects late to need and over budget to the customer. Using a dataset of 25 Afghan wartime projects, we seek to find factors that affect the success of construction projects. Current literature suggests that wartime projects may face the same cost and schedule factors as peacetime projects, with some notable additions. Using peacetime factors as a baseline, project factors, health and safety compliance, quality of work, technical performance, work productivity, and external environmental factors were tested with contingency tables to determine if they are predictive of schedule or cost performance. We found that external environmental factors, to include weather and wartime security, were not predictive of project performance. However, cost performance and schedule performance was found to be significantly dependent on government-issued excusable delays. Moreover, project management deficiencies were predictive of poor schedule performance but not cost performance.

Introduction

The construction industry uses three primary, interrelated performance metrics to measure project performance: cost, quality, and time (Chan, et al., 2002). All three of

these metrics are interrelated. For example, poor schedule performance in construction can be a result of poor quality, thus requiring rework, which drives cost increases. Reichelt and Lyneis' systems dynamics model found the relationship between project management, quality, work to be done, and rework, to be a very dynamic feedback process, containing many complex variables. Additionally, they found that increased pressure on a constructor to finish a project quickly creates positive and negative reactions (Reichelt & Lyneis, 1999). Similarly, Flyvbjerg also found that cost growth is dependent on schedule growth (2004). Even though the same potential for schedule and budget overruns exists on all projects, there is significant variance in the ultimate outcomes for each project. While this variance impedes the identification of global factors that influence cost, quality, and time (Reichelt & Lyneis, 1999) it is still possible for other researchers to perform identify factors within local jurisdictions. In general, the most cited causes of delay are engineering/design, external environmental factors, labor, material quality or material availability, project management, subcontractors, and weather (Al-Momani, 2000; Assaf & Al-Hejji, 2006; Mansfield, et al., 1994; Marzouk & El-Rasas, 2014). These researchers have concluded that the initial risk of delay in a construction project is high, regardless of additional factors. However, when construction projects are executed in environments where risk factors are at a heightened state, such as Afghanistan, the schedule delay risk increases dramatically. (Affleck, et al., 2011; Kremers, et al., 2010)

As of June 2014, the United States (US) had spent nearly $100 billion on the rebuilding effort in Afghanistan, and had allocated $23.1 billion specifically for construction projects (GAO, 2014). The Department of State and the Department of

Defense (DoD) have managed the majority of construction in Afghanistan. The two primary construction agents are the Air Force Civil Engineer Center (AFCEC) and the United States Corps of Engineers (USACE) (Thibault, 2011).

Although it has long been established that Afghanistan projects have performed quite poorly on average (Thibault, 2011), there is neither research on primary causes of severe schedule delays for AFCEC projects nor quantitative research on wartime construction delays or budget problems. One of the largest operational differences between AFCEC and USACE is that AFCEC uses an Indefinite Delivery, Indefinite Quantity (IDIQ) contract with a pre-approved list of Western-owned prime contractors that have exclusive access to projects that are advertised from AFCEC. These prime contractors are then incentivized to hire local-national subcontractors in Afghanistan. In contract, USACE uses a firm fixed price (FFP) lowest-price technically acceptable competitive bidding system. Historically, USACE has been forced to terminate many failing projects, while, as of January 2015, AFCEC has only been forced to terminate one contract. Despite this high rate of project completion, AFCEC projects still experience high schedule and cost overruns. As previously stated, there are many factors that affect the performance of a project: project management, procurement, external environment, procurement procedures, human-related factors, and project-related factors (e.g. scope, size) (Chan, et al., 2004). Currently, it is not known which factors play the largest role in the time delay of completion, especially in wartime construction projects. Therefore in this paper, we seek to understand how predictive of schedule or cost are project factors, health and safety, quality, technical performance, productivity, and external environmental factors in wartime construction projects? The factors listed in the research

question were chosen because they are most appropriate for a quantitative evaluation of project performance. Other factors are more appropriately evaluated through qualitative analysis and surveys.

A small amount of research has been performed on construction challenges in Afghanistan; and most of it comes from government oversight agencies. The United States government provided extensive oversight to the Afghanistan reconstruction effort. Auditing agencies were the Commission on Wartime Contracting, Special Inspector General for Afghanistan Reconstruction (SIGAR), Government Accountability Office (GAO), and many others. This “in-house” oversight has served to reveal many of the setbacks and problem areas within the reconstruction; however none of the research has attempted to predict how these problems may be anticipated in the future. Thus far, SIGAR has published a number of case studies on specific projects that reveal mistakes and problems, but very little cause-effect analysis has been performed, and none of it has been quantitative.

Additionally, very little research has been conducted to understand the root causes of delays in US-funded Afghan construction. In 2010, USACE released a qualitative report on their managed projects in Afghanistan that drew upon interviews with their construction management team. Using interviews, Jaszkowiak (2012) investigated differences between AFCEC Cost-Plus-Fixed-Fee (CPFF) and Firm-Fixed Price (FFP) contracts in Afghanistan. However, no quantitative research has been performed, for either USACE or AFCEC, to investigate the causes of schedule delays in Afghan projects. Studies modeling construction delays have already been performed in many countries (Al-Momani, 2000; Flyvbjerg, et al., 2004; Halligan, et al., 1994; Hoffman, et

al., 2007; Ng, et al., 2001; Reichelt & Lyneis, 1999; Skitmore & Ng, 2003); however, predictive models from other regions and external environments may not exhibit the same behavior of a wartime environment as Afghanistan.

The data for this research effort comes from the AFCEC construction program. The data come primarily from the daily reports submitted to AFCEC by on-site Quality Assurance (QA) engineers. These reports contain quality shortfalls that the QA's identified and reported to AFCEC. These reports contain many comments and observations regarding deficiencies and other project problems that can be used in statistical modeling, all of which ultimately may affect the progression of the project. The many combinations of different problems that occur in Afghanistan projects may form patterns which can be statistically shown to affect the schedule progress of the project.

Literature Review

The Air Force Civil Engineer Center (AFCEC) has been responsible for over $2 Billion in construction for the NATO Training Mission in Afghanistan. Through the course of the program, some projects performed well, and some projects performed poorly. But through it all, one primary question has been asked: how does a project manager recognize a quality project from a poor performing project? To this point, no research has been done for wartime projects that attempt to predict schedule performance. This research will use statistical tools to identify which factors are more closely correlated with schedule performance of these wartime construction projects.

Researchers have used simple regression models to predict schedule and cost performance in construction projects. An early model, developed by Bromilow (1969),

using data from 309 Australian projects, predicted the construction time based on an exponential model that included three factors: cost of the project in millions of dollars, customer's average time performance for a $1 million project, and a constant which describes the relationship between time and cost. In a recent test of the Bromilow's time-cost (BTC) model on 856 U.S. Air Force facilities constructed from 1988 to 2004, the model explained 37% of the variability. This is a notably high percentage, considering the complex nature of construction projects, which tends to inflate the variance (Hoffman, et al., 2007). Another study performed on a set of Australian projects further confirmed the accuracy of the model (although the curve coefficient behavior demonstrates a tendency to change with time and location) (Ng, et al., 2001). While Bromilow's model is not applicable to this research, it further confirms that there is a strong relationship between schedule length and ultimate cost. This further emphasizes the need for a model that can explain schedule length.

While Bomilow's model may be useful for long-term costing for companies and clients, research suggests that project management and project decisions may benefit more from multivariate regression models. Russel and Zhai (1996) used multiple-regression to predict contractor failure using economic and financial variables. The used economic factors for input variables, such as interest, value of the work after construction, and assets and working capital of the contractor. Their model successfully classified 18 of 23 contractors, 13 of which had failed (Russell & Zhai, 1996). Additionally, an Australian study performed by Skitmore and Ng (2003) used client sector, contractor selection method, contractual arrangement, project type, contract period, and contract ultimate cost to predict final cost of a set of residential projects. The

challenge with this and Bromilow's model is that the final cost must be estimated for the project. Thal et al. (2010) used regression successfully to predict the final cost of 203 construction projects for the purposes of allocating contingency funds. The researchers used normalized design length ratio, defined as the length of the design divided by the cost of the design, as one of the primary input variables. Other predictive input variables were the estimated and programmed costs respective to the actual cost awarded to the contractor.

The literature review suggests that wartime projects face the same cost and schedule factors as peacetime projects with some notable additions. A review of multiple studies from other countries in surrounding regions shows that, while some minor causes of schedule delays tend to vary depending on culture and geographic location, major causes seem to hold constant across environments, namely: design problems, planning problems, weather interference, unskilled workers/quality problems, and difficulty working with the owner or lack of direction from the owner, and change orders or scope changes (Mansfield, et al., 1994; Assaf & Al-Hejji, 2006; Ibbs, 2012; Marzouk & El-Rasas, 2014; Olima & K'akumu, 1999). Specific to Afghanistan, USACE is the only organization, thus far, that has published any researched causes for delay (Affleck, et al., 2011). The researchers performed interviews and surveys with USACE personnel, as well as local national personnel who were involved in the construction process, to gain insight into key problems experienced during US-funded construction projects within Afghanistan. As can be seen in Table 1, Affleck found both parallels and unique conditions in Afghanistan relative to the broader literature review.

Table 1 – Qualitative Construction Problem Comparison

Cause of Delay	Middle East (Peacetime)	Afghanistan
Security Problems (theft and attacks)		X
Physical Environment (Weather, Terrain)	X	X
Cultural Environment		X
Economic Environment	X	X
Political Environment	X	X
Poor Design	X	X
Slow Design	X	
Labor/Manpower Shortage	X	X
Quality of Work	X	X
Bidding System/Selection Process	X	
Contractor Financial Problems	X	
Material Supply Problems		X
Poor Owner Management	X	X
Poor Contractor Management	X	
Corruption and Bribery		X

The USACE survey found that security concerns such as theft and attacks to be the largest construction problem. It primarily occurred in the design and construction phases of the projects, and had a direct impact on material supply problems (Affleck, et al., 2011). This issue is not as prevalent in peacetime research. Berg, et al. (2005) interviewed 102 individuals in the American construction industry in order to determine average losses due to theft and vandalism on construction projects. Larger construction companies suffered more instances of theft, and smaller construction companies suffered more instances of vandalism. There was no significant trend to conclude that all

companies experience significant losses due to theft or vandalism. Indeed, many contractors do not seek claims for losses as they are below insurance deductibles. While theft can be a potential problem for construction projects, its impact seems to be greater in wartime than peacetime.

The physical environment is frequently cited in both Afghanistan and industry literature. Afghanistan construction managers believed that there was often improper planning for weather conditions on the part of the contractor. These weather conditions ranged from heavy snow to heavy rain, and often were linked to the physical environment or terrain in the vicinity (flooding was a common problem). Low temperatures in some parts of the country were frequently cited (Affleck, et al., 2011). Industry research also shows that weather is a commonly cited factor. However, little mention is made with regard to weather planning; only poor weather at a greater frequency or severity than was anticipated (Sweis, et al., 2008; Assaf & Al-Hejji, 2006; Chan, et al., 2004). Typical construction contracts allow for severe weather as a noncompensable delay (Howell, 1982-1983), which grants additional time for the contractor to finish the project, but no additional funding (Smith, Currie & Hancock, 2009; GSA, 1984). But there is no difference in opinion on weather's effect of wartime and non-wartime projects.

The next problem found by USACE was the incompatibility of western requirements with the culture of Afghanistan. This incompatibility either rendered the project useless to the end-user, or it required significant rework in both design and construction phases. Frequent turnover of USACE personnel in and out of Afghanistan, as well as jobsite safety, were also listed as significant problems (Affleck, et al., 2011). While the cultural environment is briefly mentioned by Chan (2004) when discussing all

factors that may affect a construction project, it typically is not mentioned as a significant influence. Research has shown that cultural effects can have significant effects in construction, especially when there are distinct cultural and ethnic differences between the project management team and the indigenous population. Kremers found cultural effect magnified construction problems in wartime projects. (Kremers, et al., 2010). Pheng and Yuquan studied the Singaporean and Chinese construction industries, which often are forced into cooperative situations. The cultural difference between people of the two countries were significant, and in order to aid productivity, both groups were forced to make significant changes and concessions (Pheng & Yuquan, 2002). Moreover, Baba found significant cultural differences between western and eastern cultures construction management techniques. (Baba, 1996). Additionally, a study of dispute resolution in foreign-related Chinese projects found distinct differences between western cultures methods of executing contracts and resolving problems; particularly in legal matters(Chan, 1997). Therefore, while there is no specific evidence to highlight the effect of cultural differences on project performance, related research suggests that cultural differences may be a significant factor on project performance in wartime projects.

The bidding process has frequently been cited in the construction industry as a primary cause of project problems. Simply put, the traditional policy of "lowest bid wins" frequently results in the contractor underbidding. (Assaf & Al-Hejji, 2006; Sweis, et al., 2008) Consequently, Assaf and Al-Hejji have found associations between the bidding process and the contractor's financial problems. (Assaf & Al-Hejji, 2006) Despite these well-known behavior patterns seen in the construction industry, these problems were not mentioned in the Afghan USACE report.

Material supply problems were cited in the USACE study as a significant cause of problems, namely due to the remote nature of Afghanistan itself. Quality materials are difficult to acquire there, and usually need to be imported. (Affleck, et al., 2011) Industry research does not make mention of this problem in association with frequent project delays, which is logical, considering that Afghanistan is among the remotest and harshest of construction environments.

Of the last two differences in Table 1, one was mentioned in industry literature, and one mentioned in the USACE study. The first was poor project management, which has been a focus of the construction industry for some time (Chan, et al., 2004; Sweis, et al., 2008). However, it is interesting that the Afghanistan study made no mention of poor project management from the contractor or government, which has been a notable problem in the Afghanistan reconstruction effort for some time (Kremers, et al., 2010; GAO, 2014; Thibault, 2011). The final difference, corruption and bribery, was mentioned in the USACE study as well as by Kremers (2010), but not industry literature. This problem is cultural in nature, and usually was tied to the either the local populace surrounding the project, or the local governmental or military authority. Therefore, it makes sense why this problem was not mentioned in the industry literature for more developed and less war-torn countries. It will be important to consider this problem in future reconstruction efforts, particularly due to the nature of war and how it affects business ventures such as construction projects (Kremers, et al., 2010).

There is a small amount of research which attempts to predict construction budget or schedule failure. A quantitative model by Russell & Jaselskis (1992) successfully predicted construction failure in 15 of 17 failed projects. Additionally, it correctly

predicted success in 16 of 19 successful projects. The predictive factors used were, owner evaluation of the contractor, cost monitoring performed by the owner, contractor project manager support by senior management, and early contractor project manager involvement. They recommended that owners develop robust systems for evaluating contractors prior to award, and also for closely monitoring costs and expenditures (Russell & Jaselskis, 1992). In a separate study, Russell & Jaselskis (1992) also performed an evaluation of failed projects to compare project failure criteria for evaluating on-going projects. For public projects, they found that the initial cost and estimated duration were both shorter for failure cases. However failed projects' increase percent in cost was over five times that of successful projects, and schedule growth more than three times greater. Cost and safety monitoring was also significantly lower for failed projects than successful projects. They also suggested the development of more robust evaluation procedures for contractors in public contracts but admitted that this process may encounter legal and political challenges (Russell & Jaselskis, 1992). In support of these results, Severson et al. (1994) used contractor finance data to predict whether or not a contractor would breach a contract and be forced to resort to bond claims. Their results further supported the recommendation that, to reduce the probability of default, owners should thoroughly evaluate contractors prior to award.

With regard to quantitative construction research in eastern countries, only one basic study was found. Al-Momani (2000) performed a study in Jordan using 130 projects of differing categories (residential, administrative, school, medical, and communication) to determine delay cause and time impact. He found that 24.6% experienced delays from poor design, and 15.4% experienced delays from change orders.

Overall, all project genres had a mean actual completion time significantly longer than the planned completion (Al-Momani, 2000).

Another method to determine inputs for a model is using key performance indicators (KPIs) identified in current literature. Chan's meta-analysis of KPIs found that time and cost are the primary objective indicators of a successful project and health, safety, and financial performance are secondary indicators. Additionally, his study found quality to be the primary subjective indicator of a successful project with customer satisfaction, technical performance, and productivity as secondary indicators (Chan 2002). To achieve project success, Chan et al (2004) identified five general categories of factors: project management actions, project procedures (procurement and tendering), external environment, human-related factors, and project-related factors (i.e. type, nature, size, number of floors, and complexity). Gonzales et al. (2014) also developed a qualitative framework by which researchers can evaluate root causes of delays in construction projects. They tested their methodology on three projects and found that planning, subcontracts, labor, and materials were the top reasons why the projects had been delayed. They admitted that it was not possible to perform causational analysis from the frequency of problems alone. Quantitative analysis is required for causation to be inferred. However, their results provide a helpful means by which to investigate root causes of delays (González, et al., 2014).

Ultimately, there exists a lot of research that uses qualitative study or linear regression to determine general causes of delay; unfortunately there does not appear to be significant research that attempts to use more specific variables to predict construction delays. Therefore, this research will be exploratory in nature, and will seek to find

specific factors that are predictive of project progress. Because no significant research has been performed in this area to develop a methodology successfully, this paper will use independent variables from a variety of research: past linear regression studies, key performance indicator studies, surveys of experts that indicate primary causes of delays, and root-cause analysis case studies.

Methodology

The analysis explored construction inspection reports from 25 AFCEC projects using contingency tables to determine if project factors, health and safety, quality, technical performance, and productivity, and external environmental factors are predictive of schedule or cost performance in wartime construction projects. This research focuses on three primary aspects of the data: project factors, performance factors, and environmental factors. The project factors are basic metadata with regard to each project. Examples are award, contract length, and number of contract modifications. Performance factors are related to major construction, design, and material, deficiencies cited by the quality assurance engineer. Environmental factors are related to all external environmental factors which are outside the control of the contractor. Examples are weather, interference from locals, and security threats. All the factors were analyzed to investigate the effect on the schedule and cost. Input factors for analysis were developed based on a combination of the literature review and a basic breakdown of construction discipline types. They are shown in Table 2.

Table 2 – Analysis Factors

Project Factors
Award Amount
Final Cost
Awarded Cost Growth (Index)
Number of Contract Modifications
Number of Change Orders (Scope Changes)
Initial Period of Performance
Initial Period of Performance
Final Period of Performance
Awarded Schedule Growth (Index)

Performance Factors
Quality Factors
Horizontal work (Concrete and/or Asphalt)
Building Foundation (Concrete/Rebar/Soils)
Electrical (High and Low Voltage, Comm Lines/Outlets)
Mechanical (HVAC, Gas, Boilers)
Utility (Water, Sewer, and Storm)
Structural (Masonry, Steel, and Wood)
Interior Finishing (Doors, Tiles, Walls, Ceilings, Bathroom Fixtures, Paint)
Exterior finishing (Windows, Exterior doors, Garage Doors, Fences)
Technical Performance Factors
Design Performance
Material/Submittals
Health and Safety
Safety Incidents and/or Deficiencies

External Environmental Factors
Region of Afghanistan
Security Incidents
Other External Environment Issues
Weather

The primary data source for this research was the daily reports, provided by the quality assurance engineer, for each of the 25 projects. Each report contains significant project factors, quality discussion (positive and negative), incidents, mishaps, safety information, progress information, and more. The average award cost was $25.5 million, and the average final cost of the projects was $33.2 million. The majority of the projects focused on vertical construction, with some horizontal construction. Table 3 provides summary data regarding the projects.

The daily quality reports were coded by type of factor (cf. Table 2) yielding the independent variables for this study. When an occurrence of a factor was encountered in the review of the daily reports, the incident was recorded. Each occurrence was independently linked to the project and all of the meta-data associated with that project. This allowed for a summary coding for each project, which then allowed for differentiation between projects, based on cost and schedule performance.

Table 3 – Project Data

Project Information	**Mean**	**Median**	**Standard Deviation**
Award Amount	$25.5 M	$17.0 M	$21.4 M
Final Cost	$33.2 M	$23.9 M	$28.7 M
Number of Contract Modifications	8.73	7	3.94
Change Orders (Scope Changes)	2.93	2	2.40
Initial Period of Performance	383	365	145
Final Period of Performance	823	741	354

Weather was the most commonly reported external environment issue, followed by security incidents, and then any other external environmental issue, which ranged from locals and the Afghan National Army interfering with the project, to a swine flu

outbreak halting progress on several projects for multiple days. Most projects had fewer than 40 days of weather delays. The maximum number of delays days due to security was 18, however, the majority of the projects had fewer than 6 days cited. A summary is shown in Table 4.

Table 4 – External Environmental

Factor	Mean	Median	Standard Deviation
Security Incidents (days lost)	5.32	3	6.08
Other external environmental issues (days lost)	6.60	1	11.70
Weather (days lost)	20.32	12	21.95

There was also significant variance in the number of performance deficiencies noted between the projects. The most common performance problems were with the design and material submittals of the project. Because of the thorough government review system, there were no recorded incidents of poor engineering, which led to a failure. However, as a corollary, the most common problem was contractors submitting finalized designs that did not address all the review comments, causing many unnecessary review/resubmit cycles. The majority of projects had between 0 and 15 design performance incidents, with one project that had 31.. For material and submittal deficiencies, the contractor was often late in submitting material submittals, and also commonly ordered materials that did not coincide with the original submittal. However, most projects maintained an incident rate of 5 or less, with three projects being above that, and one as high as 24.

Of the eight quality factors, four had significant variance. The most common quality problem was electrical work (M=4.0, SD = 6.72) (both high and low voltage).

The project with the most electrical problems had 28 recorded incidents. Rate of electrical incidents were slightly more distributed (between 0 and 20), and the highest count was 28 incidents. Structural issues were reported second most commonly (M=3.0, SD = 4.85), the projects with the most structural issues had respectively 14 and 20 incidents.. Foundation problems were also common (M = 2.7, SD = 5.8); most projects did not have many foundation problems, but two projects had 12 and 28 respectively. Lastly, utility issues (M = 1.7, SD = 2.72) had two outliers with 8 and 11 incidents. A summary of project performance is provided in Table 5.

Table 5 – Project Performance Summary

Deficiencies (No. of occurrences)	**Mean**	**Median**	**Standard Deviation**
Project Management	1.37	0	2.06
Contract Management	1.70	0	2.75
Design Performance	6.52	5	6.51
Material & Submittals	4.07	2	4.95
Safety Deficiencies	2.56	1	5.22
Reportable Safety Incidents	0.76	0	1.33
Horizontal work	0.78	0	1.90
Building Foundation	2.70	1	5.77
Electrical	4.00	1	6.72
Mechanical	0.52	0	0.90
Utility	1.74	1	2.72
Structural	3.00	1	4.85
Interior Finishing	0.85	0	1.37
Exterior finishing	0.48	0	0.56

The data was coded by type of factor. Each factor was assigned a number, and when an occurrence of a factor is encountered in the review of the daily reports, the number will be assigned to that specific day of the project. Each occurrence was independently linked to the project and all of the meta-data associated with that project.

This allowed for a summary coding for each project, which will then allow for easy differentiation between projects, based on cost and schedule performance.

The contingency tables were used to test independence between the project factors (cf. Table 2) and cost or schedule. Contingency tables use categorical variables to sort occurrences of incidents, and then create marginal probabilities. They then use a multinomial experiment that tests for independence between the categorical outcomes (McClave, et al., 2011). They are a common tool for analyzing categorical data where the researcher is trying to determine the dependence versus independence. The Fisher's exact test was used to analyze the contingency tables due to the small sample size. Contingency tables have been used to analyze procurement methods in the construction industry to determine which factors are most predictive of overall schedule performance (the study was not able to show any dependent factors with regard to cost) (Naoum, 1994). Likewise, Cheng, et al. (2010) used contingency tables combined with other descriptive statistics to determine factors that cause construction accidents for small companies in Taiwan.

As contingency tables require categorical data, the project factor quantitative data was converted into qualitative categories. Every category had a large grouping of incidents of a certain deficiency (usually ranging from 0 to as high as 5 incidents), and each distribution had several outlier projects. The major "breakpoint" (where the largest grouping of projects ended) was nearly always at the 75th percentile; although there were some cases when it was at the 50th percentile. These breakpoints then served as the means of determining whether a project possessed a "normal" value for that factor or not. The breakpoints for all factors are shown in Table 6 (note that unless otherwise indicated,

the units reference to the number of incidents). When a project's factor was less than or equal to the breakpoint, the project was nominally coded with a "0". When a factor was greater than the breakpoint, the project was assigned a "1". These assignments determined which row of the table a project would be assigned to (e.g. a project which had even one reportable safety incident would be assigned a 1, because it had greater than 0 reportable safety incidents). To determined the column, projects which performed within budget were assigned a "1", and assigned a "0" if over-budget. Projects that met their contractual schedule requirements were assigned a "1", and those that did not were given a "0".

The dependent variables for this study were calculated based on schedule and cost performance; they were considered either behind schedule or ahead of schedule/ on-schedule and over budget or within budget. As no two projects are alike in their project performance, the amount that a project finished ahead of or behind schedule was normalized to an index (e.g., contract 365 / actual 400 = 1.2) The index was shown as a distribution and analyzed for "break points" where there is a natural divide between certain severities of behind or ahead of schedule to provide qualitative categories from which the quantitative response variables were separated. Additionally, to subjectively evaluate the joint budget and schedule of projects, earned-value analysis was performed by using either iterative schedule updates, or the invoice account data, both provided by the construction agent. The earned value plot was measured to determine the percent of the total duration that a project was over-budget or under-budget, as well as for schedule. Additionally, the quality assurance engineering performed multiple evaluations of the project schedule, as well as their own evaluations of the earned value. Their qualitative

comments were extracted from the daily reports. As a final step, the general classification was validated by the construction agent for accuracy.

Table 6 – Nominal Break Points

Project Information	Break Point
Award Amount	$19 M
Final Cost	$21.19 M
Awarded Cost Growth (Index)	1.26
Number of Contract Modifications	9
Initial Period of Performance	868 days
Final Period of Performance	842 days
Awarded Schedule Growth (Index)	2.2
Security Incidents	5 days
Other external environmental issue	8 days
Weather	19 days
Project Management	1
Contract Management	2
Design Performance	5
Material & Submittals	5
Safety Deficiencies	3
Reportable Safety Incidents	0
Horizontal work	1
Building Foundation	2
Electrical	4
Mechanical	0
Utility	2
Structural	2
Interior Finishing	1
Exterior finishing	0

Results

Four factors had a causal relationship with cost or schedule growth, each with one degree of freedom. Cost growth was predicted by awarded schedule growth and the final project, and cost growth was reduced by mechanical issues. Schedule growth was

predicted by awarded schedule growth and project management issues. Budget performance was dependent on the final cost of the project, but not the awarded cost. Budget performance was also found to be positively dependent on the presence of mechanical issues, implying a project's budget performance improved given the presence of HVAC deficiencies. Awarded schedule growth was predictive of both cost and schedule growth. Awarded schedule growth occurred when the government awarded the contractor uncompensable excusable delays or additional time for scope changes. Thus, projects were more likely to be over-budget when additional time was granted to complete the project. Lastly, schedule performance was also dependent on whether or not the project experienced project management-related issues.

Table 7 – Contingency Table Results for Budget Performance

Level	**Over Budget** (n=10)	**Within Budget** (n=15)	**Fisher's test p-value**
Final Cost ≤ \$21.19M	4.0%	32.0%	0.0405
Final Cost > \$21.19M	36.0%	28.0%	
Awarded Schedule Growth ≤ 2.2	8.0%	44.0%	0.0154
Awarded Schedule Growth > 2.2	32.0%	16.0%	
Mechanical issues = 0	40.0%	32.0%	0.0202
Mechanical issues > 0	0%	28.0%	

Table 8 – Contingency Table Results for Schedule Performance

Level	**Over Schedule** (n=15)	**Within Schedule** (n=10)	**Fisher's test p-value**
Awarded Schedule Growth ≤ 2.2	20.0%	32.0%	0.0414
Awarded Schedule Growth > 2.2	40.0%	8.0%	
Project Management issues ≤ 1	28.0%	36.0%	0.0405
Project Management issues > 1	32.0%	4.0%	

While correlation is not causation, correlation tests were conducted to further explain the common trends among the study variables and to identify factors that may have indirect relationships. Table 9 shows statistically significant correlations that are related to the primary factors that may possess an indirect relationship with schedule or budget performance.

Table 9 – Kendall's Correlation Test (Secondary Factors)

Variable	**by Variable**	**Kendall T**	**Prob >|T|**
Awarded Schedule Growth (Index)	Final Period of Performance	0.3533	0.0133
Final Period of Performance	Final Cost	0.54	0.0002
Final Period of Performance	Initial Period of Performance	0.4348	0.0024
Final Period of Performance	Award Amount	0.42	0.0033
Final Period of Performance	Number of Contract Modifications	0.3267	0.0267
Initial Period of Performance	Final Cost	0.3545	0.0133
Interior Finishing	Mechanical	0.44	0.0165
Mechanical	Material & Submittals	0.3985	0.0216
Mechanical	Safety Deficiencies	0.3851	0.0297
Number of Contract Modifications	Final Cost	0.3406	0.0209
Number of Contract Modifications	Award Amount	0.2919	0.0477
Utility	Mechanical	0.4838	0.0064

Discussion

The predictive factors for schedule and budget performance are those commonly seen in peacetime projects. Project management issues and awarded schedule growth is predictive of schedule performance problems; final cost and awarded schedule growth are predictive of budget performance problems. Correlation results agreed with the

contingency table results and provided additional insight regarding the relationships. The external environment factors were not found to have a significant effect.

Performance Factors.

The significant effect that management can have on the performance of a project should never be underestimated. The contingency tables showed that project management deficiencies are predictive of schedule performance, $p < 0.05$, which was the only significant performance-related factor. This confirms what previous researchers have stated about the criticality of project management in the overall performance of a project (Assaf & Al-Hejji, 2006; Chan, et al., 2004). Project management deficiencies also correlated negatively with schedule performance, $r = -0.36$, $p < 0.05$. The more project management deficiencies that were cited by QA engineers, the more likely it was that a project would be behind schedule.

Cost.

The contingency tables found dependency between the project's final cost (above or below \$21.19M) and its budget performance, $p = 0.04$. However, no relationship was found based on the initial cost of the project; $p = 0.11$. Thus, the data does not seem to suggest that higher-cost projects are inherently at a higher risk of budget overruns; instead, it suggests that there is a second-order effect causing the budget performance issues. One possible mediating factor is contract modifications. They were correlated to both the award amount, $r = 0.29$, $p < 0.05$, and the final cost of projects, $r = 0.34$, $p < 0.05$. Final period of performance also increased whenever contract modifications were introduced, $r = 0.33$, $p < 0.05$. Additionally, final cost was shown to correlate significantly with both the initial, $r = 0.35$, $p < 0.05$, and the final period of performance,

$r = 0.54$, $p < 0.001$, showing there may be a triangular relationship between cost, schedule, and contract modifications. These relationships may imply that the number of contract modifications increases with project scope and not solely cost growth. However, the price increases that inevitably come with changes appear to be stronger in the final cost of the project than the initial award amount. This could confirm the traditional theory that contractors bid low to win a project with the intent of "making it up with change orders"; or it could simply recognize that larger projects tend to be more complex and have more risk for change. Ultimately, as has been shown in previous studies (Assaf & Al-Hejji, 2006; Chan, et al., 2004; Mansfield, et al., 1994), there remains a connection between contract modifications and cost measures.

Awarded Schedule Growth.

Another result of the study is the dependent relationship that schedule and cost performance has with the allowance of additional time to construct a project $p < 0.05$ for both cases. Not surprisingly, given the construction location and wartime environment, every project was granted some additional time to finish by the contracting officer. Yet this practice increased the likelihood that a project would be considered late and over-budget. Additionally, correlation for cost performance supported the contingency table results, $r = -0.43$, $p = 0.01$. An interview with the AFCEC program manager confirmed these empirical results. The contractors in Afghanistan would often struggle to regain momentum when they experienced some kind of delay; even when the delay was compensable or excusable. Oftentimes, if the delay was compensable, contractors would end up fronting money to keep the project functioning while the government arranged proper compensation. But the contractor would sometimes lose too much capital, which

then required them to lay-off staff and labor (Schoenenberger, 2014). This also may indirectly caused delays.

Period of performance.

The final period of performance correlated significantly with multiple factors: final cost, $r = 0.54$, $p < 0.05$, award amounts, $r = 0.42$, $p < 0.05$ the number of contract modifications, $r = 0.32$, $p < 0.05$, awarded schedule growth, $r = 0.35$, $p < 0.05$, and initial period of performance, $r = 0.43$, $p < 0.05$. It is easy to dismiss the latter two factors because the schedule ought to correlate with other schedule factors. However, the relationships between two cost factors, initial and final cost, the initial performance period also correlating with final cost, as well as the number of modifications received within a project, may imply that the final length of a project could be predicted by a regression equation involving these factors. This has been done recently for peacetime federal projects by Hoffman, et al. (2007) and was first done by Bromilow (1969). Unfortunately, the population size for this study was not large enough to perform regression analysis. However, these results imply that wartime project could use peacetime factors to predict the total time to construct with some amount of accuracy. If this research were performed real-time in future long-term wartime construction efforts, a prediction model could be built and updated to increase accurate predictions for beneficial occupancy dates.

Mechanical.

In the contingency table tests, budget performance was shown to be positively dependent on mechanical deficiencies, $p = 0.02$. All of the projects that experienced mechanical difficulties were within budget parameters. It is unknown why the

relationship between budget performances improved with mechanical problems; to investigate possible causality sources, correlation tests were performed. Mechanical issues correlated positively with safety deficiencies, $r = 0.38$, $p < 0.05$, material and submittal problems, $r = 0.39$, $p < 0.05$, interior finishing deficiencies, $r = 0.44$, $p < 0.05$ and utility deficiencies $r = 0.48$, $p < 0.05$. Based on these findings, causality was tested using contingency tables. Structural and interior finishing deficiencies were found to be significant, $p = 0.02$ and $p < 0.01$, respectively. Unfortunately, this did not explain the relationship between mechanical deficiencies and budget performance.

Mentionable Lack of Results.

Weather was not found to be a significant factor. The breakpoint was determined to be at 19 days of delay, roughly the same as the mean (M = 20.2, SD = 22.0). Seven projects had less than 19 days of delay and 18 projects had more. Projects determined to have more severe weather delays ranged from 22 days to 77 days. It was observed that there were three outlier projects in the distribution that had significantly more weather delays than the remainder of the projects. This finding disagrees with previous research by Assaf & Al-Hejji (2006), who found that most construction professionals believe weather is a significant cause of delay. Although it is difficult to draw conclusions from insignificant results, this may imply that weather's environmental influence is diminished in a wartime environment because of other environmental factors, such as labor availability.

There were not any significant results regarding security incidents or any other external environmental delays. It is still assumed in this research that these environmental issues have a stronger influence on project performance than in peace-time projects.

However, this research was unable to yield any significant results to substantiate this assumption. It is possible that the effect of these factors is diminished with AFCEC projects compared to USACE projects. According to the construction agent, AFCEC maintained stricter security and oversight requirements on the part of the contractor (Schoenenberger, 2014). This may have reduced the number of incidents that occurred on AFCEC projects. To substantiate this, further research should be done on the external environment and then compared to different population samples.

Conclusion & Recommendations

Initially in this research, it was thought that performance and environmental factors would be very predictive of project performance; perhaps even more so than project factors. However, project factors tended to be more predictive of budget and schedule performance than either of the other two categories. The correlation relationships also suggest that project factors and overall performance, are not tied to performance factors. Additionally, external environment did not have a significant effect on the schedule and budget performance of a project. Analysis of these results brings forth several recommendations.

Minimizing the additional time granted to the contractor may also improve schedule performance. The research found that when additional time was granted to the contractor by the government, the likelihood of cost growth and schedule growth increased. The construction agent suspects that this may be related to the original period of performance that is often assigned to projects in wartime environments. In some cases, they believe that not enough time was originally given for contractors to complete their

projects. Indeed, this exactly what Russell and Jaselskis (1992) found in their contractor evaluation research: failed projects estimated a significantly smaller period of performance than successful projects. Additionally, Ibbs (2012) showed that any change on a project significantly increases the likelihood of failure. He discovered that changes can have an exponential effect on a project and that proper original planning may have decreased the overall schedule or budget increases. Therefore, in future contracts it may be prudent for construction agents and their owners to consider extending FPOP's; which may reduce overall cost and schedule overruns.

Additionally, construction agents should ensure a strong financial and historical evaluation of all contractors and project managers. As mentioned previously, Russell & Jaselskis (1992) found that contract failure could be directly linked to the amount of scrutiny that the owner applied to the winning contractor. Moreover, their research demonstrated the project manger's critical role in the success of the project (Russell & Jaselskis, 1992), which was reconfirmed by the results of this study: project and contract management issues are strongly predictive of poor performance.

Limitations of the study.

Unfortunately, the dataset used in this research was too small to perform regression analysis or a T-test. However, this fact does not undermine these results. The significant of the Fisher's exact test lies in its conservative nature. Fisher's test has been known to not find significance in cases where a chi-squared test may find significant results. While this research would benefit from a larger sample, the results are still significant.

The data was quantitative but derived from qualitative data. The QA engineers were solely responsible for citing performance problems, and it is expected that some deficiencies or items may have been missed. Additionally, only major deficiencies were considered for this study. The data lists many minor deficiencies that were ignored. It would be beneficial to analyze this data in future research.

Future Research.

As mentioned in the introduction, AFCEC's project execution methodology is significantly different than USACE. Future researchers should consider using USACE data for a similar study to compare the results to the AFCEC program. Moreover, additional methodology can be used in a USACE study because a large sample size should be easy to achieve.

Labor analysis may play a large role in the slowing of projects, which may be one of the reasons why schedule performance was not predicted by weather delays. According to the construction agent, many projects experienced slow progress, due to a dearth of skilled workers in-country. A fast-moving project that has a plethora of skilled laborers on site may be as more affected by poor weather than a project that is already progressing slowly. Future research should consider the effect of quality of labor as well as the number of workers that are present on-site for the project.

Similar research should also be applied to other wartime environments. Iraq is a viable candidate because it is a recent construction effort and nearly identical in purpose. Additionally, both AFCEC and USACE performed work in Iraq, which would allow for another comparison between construction agents.

Conclusion.

Much research remains in order to fully understand the difference between wartime and peacetime construction projects. The literature review shows that the body of knowledge is very small in this industry, yet the monetary expenditure has the potential to be great (e.g. Iraq and Afghanistan). Based on this research, there are many similarities between wartime and peacetime construction, which should cause construction agencies to create more strict policies for contractors, in spite of the environment. However, this research covers only a small part of the industry within one campaign. Government agencies should increase sponsorships of wartime construction to gain additional insight, saving money which could otherwise be used elsewhere.

III. Scholarly Article 2: Quantitative Analysis of Construction Contract Type Differences in a Wartime Environment

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Abstract

US-led construction projects in Afghanistan have performed poorly on average; indeed, it is the norm to deliver projects late to need and over budget to the customer. Using a dataset of 25 Afghan wartime projects, we address the question: How do project outcomes differ based on the contract type? First, with regards to critical success factors, current literature suggests that wartime projects may face the same cost and schedule factors as peacetime projects, with some notable additions. Using peacetime factors as a baseline, project factors, health and safety compliance, quality of work, technical performance, work productivity, and external environmental factors were used as dependent variables in a series of Mann-Whitney tests. We found reimbursable contracts to have significantly greater cost and schedule growth. Additionally, fixed price projects were found to have more problems with design performance and contract management. There was no significant difference in overall project quality. In conclusion, cost monitoring from the owner and scrutiny of project management is critical to the success of reimbursable contracts, and technical performance monitoring is necessary to ensure that fixed-price projects meet deadlines.

Introduction

United States inspection reports and its popular press are replete with examples of wasteful spending of taxpayer dollars on Afghanistan construction projects (GAO, 2013; GAO, 2014; Thibault, 2011; CWC, 2011; Chappell, 2013). As summarized by an American official involved in the construction program, "nobody was watching it like they should have, and it's just been an open checkbook." (Craig, 2013) The Commission on Wartime contracting estimated in their 2011 final report that at least $31 billion, but possibly as much as $60 billion could be considered "waste" during the lifetime of the Afghanistan and Iraq campaigns. (CWC, 2011) With $23 billion being allocated to wartime construction efforts as of 2014 (GAO, 2014) construction companies have had financial incentives to be involved in the US-led reconstruction effort. Construction waste can have many different meanings. It can mean poorly planned, overseen, or built projects; it can be abuse and corruption (SIGAR, 2010). Additionally, it can be the construction of unwanted or unneeded facilities or projects delivered over budget and behind schedule (Teo & Loosemore, 2001; Sopko, 2013; Thibault, 2011). In this paper, we will explore construction waste using the framework of contract types. Specifically, we will determine what construction waste occurs as a result of cost-plus-fixed-fee versus fixed-fee contracting.

The federal acquisition regulations (FAR) describes the process (FAR Part 16.103, .104) used by the US government to solicit and award contracts. The two most common contract types allowed by the FAR are the firm-fixed price (FFP) contract and the cost-plus-fixed-fee (CPFF) contract. These two contracts differ vastly in their structure and purpose. The FFP contract places the cost and schedule risk on the

contractor, while the CPFF contract shifts much of this risk to the US government to account for projects with high levels of uncertainty or risk (FAR Part 16.101 b). The idiosyncrasies of each contract type have caused contractors to behave differently in their interaction with the customer, performance of the project, spending behaviors, schedule adherence (Adler & Scherer, 1999). However, no research has been done to show differences in contractor behaviors across contract types in a wartime construction environment.

Limited research has been performed on the performance differences between fixed price and reimbursable construction projects. Structural differences between fixed price and reimbursable contracts have been extensively researched (Nkuah, 2006; Veld & A, 1989; Ward & Chapman, 1994; Wamuziri, 2013; Branconi & Loch, 2004) as have the types of human behaviors that are inspired by the two contract types (Müller & Turner, 2005; Osipova, 2014). However, specific causes of contract type performance differences are not fully understood (Adler & Scherer, 1999; Jaszkowiak, 2012). Consequently, owners do not fully understand how the selection of a contract type may affect project success or conversely induce waste (Veld & A, 1989). Moreover, this research may be particularly relevant to military owners who contract projects in wartime environments. While reimbursable contracts may entice companies to submit bids, they also provide significant possibility for cost growth and may need to be monitored differently than fixed-price contracts. Conversely, fixed price contracts in wartime environments may shift so much risk on contractors that it is impossible for companies to make a profit. Therefore, this research effort will use data from 25 Afghan wartime construction projects to search for factor differences between fixed-price and reimbursable projects

that cause waste. The major factors will be project attributes, health and safety, quality, technical performance, productivity, and the external environment.

Literature Review

US contract and project management personnel who have worked in the Afghanistan reconstruction efforts were ill-prepared to manage projects there. Security concerns, unqualified personnel, poor planning, improper contract solicitations, poor planning, and weak management have all contributed to waste within the US-Afghan reconstruction efforts (Thibault, 2011). To further complicate the challenges faced by the owners, the literature suggests that contract type choices will cause contractors to behave differently, depending on which contract type is used (Jaszkowiak, 2012; Adler & Scherer, 1999). This research investigated these behaviors so that construction professionals can have clearer expectations for contract performance in future wartime projects in order to minimize waste.

The contract types used in this wartime construction projects study are firm-fixed price (FFP) and cost-plus fixed fee (CPFF). In FFP contracts, the key component is referred as the *pre-calculation*, in which the contractor and the client negotiate a dollar amount separate from the actual costs of the project. The contractor shoulders the majority of the risk in this case, and the client knows in advance how much will be paid to the contractor. The owner’s risk is limited to design or specification errors (United States v. Spearin, 1918). Furthermore, the contractor’s risk is based on its ability to provide an accurate estimate that will adequately cover its costs, yield a small profit, and qualify as the lowest, but most technically acceptable, bid (Smith, Currie & Hancock,

2009). A cost-plus contract is a “cost reimbursable” contract, which require the client to reimburse the contractor for the ultimate costs of the project irrespective of initial estimates. In the case of a CPFF project, the contractor is also paid a fixed and pre-negotiated fee for their services. (Veld & A, 1989; Ward & Chapman, 1994). Thus, the owner assumes risks not only for the design but also for increases in material and labor costs. In contrast, the contractor assumes little risk as the owner underwrites the project (Nkuah, 2006).

For all federal projects, the project contracting officer is the ultimate decision-maker for which contract type used for a contract (FAR Part 16.1). Many factors must be considered when choosing a contract method such as price competition, price analysis, cost analysis, type and complexity of the project, urgency of the project, and performance period of the contract (FAR part 16.1). Certain levels of uncertainty are tolerable for a fixed-price contract, but the market typically will not accept high levels of uncertainty without adequate compensation. Therefore, with high levels of risk, it behooves the owner to assume that risk and use reimbursable contract in order to save money and time (Nkuah, 2006). Historically, reimbursable contracts are generally not used, in larger development projects due to the risk of substantial cost overruns; as is common in construction projects (Veld & A, 1989). According to the FAR, the selected contract type should maximize the value to the government.

Contract type also influences project performance. Adler & Sherer (1999) used a multi-variate methodology with transaction cost analysis (TCA) to evaluate differences between reimbursable, fixed-price, and incentive contracts in the defense aerospace industry (Adler & Scherer, 1999). TCA is the theory that the management of the contract

is based on several factors: asset specificity, uncertainty, bounded rationality, and opportunism present in the contract. It also proposes that contracts show differing amounts of control, coordination, and adaption (Williamson, 1998). The study found reimbursable projects performed better when the contractor contributes more knowledge to complete the transaction, but fixed-price contracts are more useful for purchasing projects that have well-defined requirements (Adler & Scherer, 1999). Thus, ill-defined projects, with accompanying higher levels of contractor risk, have better outcomes when coupled with reimbursable projects and well-defined requirements are better suited to fixed-price contracts. Likewise, Müller and Turner (2005) found fixed-price contracts cause owners to abdicate their project responsibilities to the contractor causing an increased likelihood of an adverse outcome. Additionally, they found that reimbursable contracts encourage contractors to ignore project objectives as they focus on possible financial gains also threatening project success.

Contract type is commonly promoted as a method for the owner to manage project risk. Braconi and Loch (2004) developed a framework of eight key business drivers and determined how fixed price, incentive, and reimbursable projects interact with the primary factors. They found that fixed price contract demand very well-defined project attributes (e.g. scope, design, estimates), but require significantly less effort from owners to ensure that contractors stay within budget and schedule limitations. Conversely, reimbursable projects are well-suited for ill-defined scopes but require heavy involvement from the owner to control costs. Incentive based contracts often provide a healthy balance of risk to both parties but are often difficult to negotiate. They propose

that fixed contracts can be written so as to reduce the risk in areas of uncertainty, thereby protecting both the owner and the contractor.

Therefore, selection of a contract type may be crucial to the business success of an owner. Veld and Peters (1989) developed a decision network by which owners can select a contract type, based on an owner's assessment of the contractor's competency and ability to manage six criteria: cost uncertainty, technical uncertainty, available extra resources, schedule criticality, performance criticality, and long-term motives. They propose that firm-fixed price contracts are never acceptable with a high cost or technical uncertainty. However, they consider high-uncertainty in the other factors to be acceptable for fixed-price projects. They make note that military and government agencies rarely use incentive methods. Ultimately, their recommendation is for project owners to consider the use of incentive contracts.

Wamuziri (2013) reached the same conclusion as Veld and Peters (1989) regarding incentive contracts in his study that focused on collaborate procurement for infrastructure projects. He found that premiums for fixed-price contracts tend to be quite high, due to the high risk born by the contractor. In opposition, reimbursable contracts, "[arguably] have reverse incentives for the contractor to drive the costs upwards." (Wamuziri, 2013) In order to inspire lower premiums and better technical performance (both which lower the risk to the owner) it is desirable to increase the number of bidders for a construction project. But incentive contracts have been shown to provide a healthy balance of risk between the contractor and the owner, fostering a joint-effort environment as opposed to high scrutiny and wariness (Berends, 2000).

Previously, it has been thought that contract type has a significant effect on bid competition and contractor competency; however previous research has shown that it is the contract size and scope that is primary predictor of competitiveness, and that perhaps the contract type is a sub-factor for (Drew & Skitmore, 1997). Indeed, some research argues that the uncertainty of the project scope and size should be the primary determinant of contract type, and other risks are considered more tertiary. As previously discussed, the business culture and relationships between the owner and the contractor may be a large predictor of the ultimate success of a project, regardless of contract type (Turner & Simister, 2001).

Despite this research, to-date, significant performance differences between fixed-price and reimbursable projects in a wartime environment have not been researched. There are many performance factors that can be analyzed. For example, Adler (1999) found that, in the aerospace acquisition industry, a fixed-price project may not require as robust of a design effort as a reimbursable project, because project complexity should be lower for a fixed-price versus a reimbursable. If this is the case, then fixed-price projects may not experience as many instances of design rework as reimbursable projects. Jaszkowiak (2012) was able to analyze contract performance metrics (e.g. cost and schedule perfect performance), but did not have data to analyze performance or management factors. This research will analyze performance factors as well as cost and schedule factors.

It is hypothesized that contract type affects project success and waste; the factors to be tested were determined by reviewing the literature on key performance indicators. Wartime projects likely face the same delay causes as peacetime projects with some

notable additions. Only one qualitative study has been performed in Afghanistan regarding project challenges; many of its observed causes of delay are common in other nearby Asian and African countries. Delays are caused by design problems, planning problems, weather interference, unskilled workers/quality problems, and difficulty working with the owner or lack of direction from the owner, and change orders or scope changes (Affleck, et al., 2011; Assaf & Al-Hejji, 2006; Mansfield, et al., 1994; Marzouk & El-Rasas, 2014; Olima & K'akumu, 1999).

The Afghanistan study found that, overwhelmingly, security concerns were the primary challenge to projects. This factor is generally unique to wartime projects. While the FAR defines delays due to acts of terror as excusable but noncompensable, the data for this study showed that attacks were often treated as a compensable delay. The frequency of security problems in Afghanistan is much higher than those experienced in peacetime construction.

The physical environment of the project is commonly mentioned in both wartime and peacetime literature. Weather conditions are one of the most commonly cited delay factors for all projects. Afghanistan has the potential for particularly harsh weather, especially in the mountainous regions. Affleck, et al. (2010) stated that planning for harsh weather was particularly poor in Afghanistan. Other industry literature does not discuss planning but does consistently cite it as a cause for delay. Most construction contracts allow for a certain number of weather delay days, but also state that is considered an excusable delay, offering no compensation except in extreme cases (Smith, Currie & Hancock, 2009).

Key performance indicators (KPI) were also used as input factors to analyze differences between contracts. Chan, et al. (2002) performed a meta-analysis of KPIs, as determined by construction researchers. They found that the most predictive performance metrics were, predictably, time and cost. Other factors are project safety and financial performance of the contractor. The largest qualitative predictors were construction quality and customer satisfaction. A follow-up study by Chan, et al (2004) developed a framework for project success and identified five categories of factors: project management actions, project procedures, external environment, human-related factors (often unpredictable or immeasurable), and project-related factors (e.g. type, size, number of floors).

Currently, there exists a large amount of research that predicts construction delays; however, very little analysis has been done to investigate performance differences between reimbursable and fixed-price contracts. This research will use the collection of the reviewed delay factors to test the differences between contract types and see if there are significant differences in waste, which may allow construction agents to oversee projects better.

Methodology

In order to understand how contract types affect waste in wartime construction projects, the Mann-Whitney median comparison test will be used to test differences among the mean for the for project factors, performance factors, and environmental factors (See Table 10). The project factors are basic metadata with regard to each project, such as award, contract length, and the number of contract modifications.

Performance factors are related to major construction, design, and material quality control deficiencies cited by the quality assurance engineer. Additionally, it includes worker health and safety compliance. Environmental factors are related to all external environmental factors which are outside the control of the contractor. Weather, interference from locals, and security threats are examples of the external environment. All these potential sources of waste were analyzed to determine if firm-fixed price or cost reimbursable contracts caused more project waste.

The response variables were obtained from an analysis of the each project's daily reports, created by the US government's quality assurance engineer. Twenty-five projects were analyzed; 11 were FFP and 14 were CPFF. Each report contained comments regarding construction quality (positive and negative) as well as daily construction activities (e.g. quality deficiencies, mock-up meetings, progress for each craft). They also documented delays, security incidents, safety mishaps or deficiencies. The average award cost was $25.5 million, and the average final cost of the projects was $33.2 million. The majority of the projects focused on vertical construction. Table 11 provides summary data regarding the projects.

Table 10 - Analysis Factors

Project Factors
Award Amount
Final Cost
Awarded Cost Growth (Index)
Number of Contract Modifications
Number of Change Orders (Scope Changes)
Number of FPOP extensions
Total days added to the contract
Initial Period of Performance
Initial Period of Performance
Final Period of Performance
Awarded Schedule Growth (Index)

Performance Factors
Quality Factors
Horizontal work (Concrete and/or Asphalt)
Building Foundation (Concrete/Rebar/Soils)
Electrical (High and Low Voltage, Comm Lines/Outlets)
Mechanical (HVAC, Gas, Boilers)
Utility (Water, Sewer, and Storm)
Structural (Masonry, Steel, and Wood)
Interior Finishing (Doors, Tiles, Walls, Ceilings, Bathroom Fixtures, Paint)
Exterior finishing (Windows, Exterior doors, Garage Doors, Fences)
Technical Performance Factors
Design Performance
Material/Submittals
Health and Safety
Safety Incidents and/or Deficiencies

External Environmental Factors
Region of Afghanistan
Security Incidents
Other External Environment Issues
Weather

The daily quality reports were coded by type of factor (i.e., Table 10) yielding the independent variables for this study. When an occurrence of a factor was encountered in the review of the daily reports, the incident was recorded. Each occurrence was independently linked to the project and all of the meta-data associated with that project. This allowed for a summary coding for each project, which then allowed for differentiation between projects, based on contract type.

Table 11 - Project Data

Project Information	Mean	Median	Standard Deviation
Award Amount	$25.5 M	$17.0 M	$21.4 M
Final Cost	$33.2 M	$23.9 M	$28.7 M
Number of Contract Modifications	8.73	7	3.94
Change Orders (Scope Changes)	2.93	2	2.40
Initial Period of Performance (days)	382.76	365	144.82
Final Period of Performance (days)	822.84	741	353.70

Weather was the most commonly reported external environment issue, followed by security incidents, and then any other external environmental issue, which ranged from locals and the Afghan National Army interfering with the project, to a swine flu outbreak halting progress on several projects for multiple days. Most projects had fewer than 40 days of weather delays. The maximum number of delays days due to security was 18. However, the majority of the projects had fewer than 6 days cited. A summary is shown in Table 12.

Table 12 – External Environmental

Factor	Mean	Median	Standard Deviation
Security Incidents (days lost)	5.32	3	6.08
Other external environmental issues (days lost)	6.60	1	11.70
Weather (days lost)	20.32	12	21.95

There was also significant variance in the number of performance deficiencies noted between the projects. The most common performance problems were with the design and material submittals of the project. There were no recorded incidents of poor engineering, which led to a failure. However, as the government had a thorough review process, the most commonly observed problem was contractors submitting finalized designs that did not address all the review comments, causing many unnecessary review/resubmit cycles. The majority of projects had between 0 and 15 design performance incidents, and one project had 31. For material and submittal deficiencies, contractors were often late in submitting material submittals, and they also commonly ordered materials that did not coincide with the original submittal. However, most projects maintained an incident rate of 5 or less, with three projects being above that, and one as high as 24. The material submittal incidents were slightly more distributed (90% between 0 and 20), and the highest count was 28 incidents.

Of the eight quality factors, four had significant variance. The most common quality problem was electrical work (M=4.0, SD = 6.72) (both high and low voltage). The project with the most electrical problems had 28 recorded incidents. Structural issues were reported second most commonly (M=3.0, SD = 4.85), the projects with the

most structural issues had respectively 14 and 20 incidents. Most projects did not have many foundation problems (M = 2.7, SD = 5.8) but two projects had 12 and 28 each. Lastly, utility issues (M = 1.7, SD = 2.72) had two outliers with 8 and 11 incidents. A summary of project performance is provided in Table 13.

Table 13 - Project Deficiency Summary

Deficiencies (No. of occurrences)	Mean	Median	Standard Deviation
Project Management	1.37	0	2.06
Contract Management	1.70	0	2.75
Design Performance	6.52	5	6.51
Material & Submittals	4.07	2	4.95
Safety Deficiencies	2.56	1	5.22
Reportable Safety Incidents	0.76	0	1.33
Horizontal work	0.78	0	1.90
Building Foundation	2.70	1	5.77
Electrical	4.00	1	6.72
Mechanical	0.52	0	0.90
Utility	1.74	1	2.72
Structural	3.00	1	4.85
Interior Finishing	0.85	0	1.37
Exterior finishing	0.48	0	0.56

The research will use the Mann-Whitney test to evaluate dependencies and differences in the analysis factors between contract types. The Mann-Whitney test is an appropriate choice for use of small-sample, non-parametric comparison between the medians of two different populations because it does not rely on data distribution. Rather, it uses a median ranking comparisons of each data-point to determine a sum-rank score, which is then converted to a hypothesis test statistic and used in a standard z-test. (Gold, 2007). Ultimately, the hypothesis test will determine if the median is statistically different between contract types and can determine if there is a significant difference in the amount

of waste as measured by the average performance of a FFP contract over a CPFF in a continuous variable, such as schedule or cost performance.

Results

The study used the Mann-Whitney pairwise comparison test with a 2-sided, normal approximation to test the hypothesized factors. The results, shown in Table 14, indicate that there are five significant factors and one near significant factor that displayed differences across contract types. The “U” value is the rank assigned to the variable; the “z” is the test statistic value and the “Sig. (2-tailed)” is the p-value for the test. Factors were determined to be significant if they possessed a p-value of 0.05 or less. The final cost, awarded cost growth, final period of performance, design performance, and contract management were significant as a result of contract type.

In the daily reports, a project management deficiency was anything associated with the poor planning or management of the work on-site. For example, oftentimes the contractor would proceed with the work without coordinating with the QA engineer, performing proper inspections beforehand, or developing and publishing a QC plan. Another example is scheduling conflicting craft disciplines in the same work area, resulting in delays and worker conflicts.

Contract management items were primarily issues where the contractor failed to meet contractual requirements. Examples are a contractor’s failure to submit an updated schedule, master plan, utility plan, progress and status updates. Another common infraction was providing proper living and working conditions for the QA engineer(s).

We took great care to ensure that design performance was defined so that these issues did not overlap with project or contract management. Therefore, these issues only included design quality and design schedule performance. Although the construction agent has now since identified several design flaws post-contract completion, there were no recorded occurrences of construction failure as a result of poor design. Late design submissions were the primary problem. As a result, the contractor often worked at risk (working at risk was not coded independently, because it was nearly always caused by late design).

The awarded schedule growth index was calculated by dividing the final government-allowed period of performance by initial contractual period of performance. This is not necessarily the actual performance period. The actual period of performance could not be used to calculate a schedule growth factor because of the inherent differences between fixed-price and reimbursable contracts. Fixed price projects are contractually able to continue in operation after the contractual completion date has expired. This is because the risk is placed on the contractor. However, reimbursable contracts must be closed out when the period of performance expires unless the owner extends the contractual completion date. Therefore, in a reimbursable contract, the actual completion date is always the same or before the contractual date. This makes actual completion dates incomparable between the contract types, which is why the contractual completion date was chosen for both projects. Moreover, the contractual completion date is within the control of the owner (whereas actual completion in fixed contracts is not), and is thereby a superior factor to compare between the two contract types.

Table 14 –Mann-Whitney test for contract types

Factor	Type	Mean	Standard Deviation	*S*	*Z*	Prob>|*Z*|
Award Amount	CPFF FFP	$25.6 $25.3	$17.6 M $26.4 M	125	-0.96	0.338
Final Cost	CPFF FFP	$37.5 $27.7	$28.6 M $29.1 M	105	-2.05	0.040*
Awarded Cost Growth	CPFF FFP	1.48 1.13	0.38 0.17	98	-2.44	0.015*
Number of Contract Modifications	CPFF FFP	10.1 7.4	4.8 1.8	124	-1.02	0.308
Change Orders	CPFF FFP	3.4 2.1	2.8 1.4	120	-1.26	0.208
Number of FPOP extensions	CPFF FFP	5.4 3.3	2.4 1.3	103.5	-2.17	0.030*
Total Days Added to Contract	CPFF FFP	591 330	275 151	97	-2.49	0.013*
Initial Period of Performance	CPFF FFP	390 373	145 145	138.5	-0.22	0.827
Final Period of Performance	CPFF FFP	945 668	400 209	105	-2.05	0.040*
Awarded Schedule Growth	CPFF FFP	2.46 1.86	0.77 0.61	107	-1.94	0.052[1]
Security Incidents	CPFF FFP	4.1 6.9	4.5 7.3	157	0.74	0.457
Other external environmental issue	CPFF FFP	5.4 8.2	8.9 14.4	151.5	0.45	0.653
Weather	CPFF FFP	22.9 17.1	22.4 21.3	126.5	-0.88	0.380
Project Management	CPFF FFP	1.3 1.6	2.1 2.2	154	0.63	0.526
Contract Management	CPFF FFP	1.2 2.6	2.8 2.7	180.5	2.15	0.031*
Design Performance	CPFF FFP	3.9 10.1	2.7 8.2	187	2.39	0.017*
Material & Submittals	CPFF FFP	6.1 2.3	8.5 3.7	119	-1.32	0.186
Safety Deficiencies	CPFF FFP	1.9 3.9	3.4 7.0	157.5	0.80	0.425
Reportable Safety Incidents	CPFF FFP	0.7 0.8	1.0 1.7	135	-0.48	0.631
Horizontal work	CPFF FFP	0.6 1.2	0.9 2.8	140	-0.17	0.868
Building Foundation	CPFF FFP	2.1 4.0	3.2 8.1	151.5	0.45	0.652
Electrical	CPFF FFP	3.4 5.0	4.6 9.1	132.5	-0.58	0.561
Mechanical	CPFF FFP	0.5 0.6	1.2 1.2	152.5	0.62	0.531
Utility	CPFF	1.7	2.9	150	0.37	0.709

Factor	Type	Mean	Standard Deviation	*S*	*Z*	Prob>|*Z*|
	FFP	2.1	2.6			
Structural	CPFF	3.2	5.3	149.5	0.33	0.738
	FFP	3.4	4.5			
Interior Finishing	CPFF	0.6	1.0	156	0.77	0.438
	FFP	1.3	1.7			
Exterior finishing	CPFF	0.6	1.2	151	0.48	0.628
	FFP	0.5	0.5			

*Signifies 2-tailed significance ($p < 0.05$). Reject null hypothesis.
[1]Nearly significant; and is significant using Fisher's Exact Test in a contingency table.

The awarded schedule growth was a near-significant factor in the Mann-Whitney test. Therefore, further investigation was appropriate. A contingency table using Fisher's exact test revealed that awarded schedule growth was dependent on contract-type (p = 0.0154).

Discussion of Results

Cost.

Reimbursable contracts were found to have significantly higher costs than fixed price contracts. This difference was found for cost increases during the life of the project and for the final project cost. Notably, there was not a significant difference between award amounts of contract types. These findings demonstrate that reimbursable contracts are likely to be awarded at similar prices to firm-fixed price contracts, but are likely to cost more at the end of the project. The validity of this conclusion is strengthened by the significant difference seen in cost growth. In the analysis, large projects were compared alongside small projects; and there may have been considerable variance between the project factors, which may reduce the credibility of a direct comparison in terms of raw cost or some other attribute. The cost growth index normalizes the projects' cost

comparisons. For example, larger projects may have differences in risk and nature of work than smaller projects. Additionally, when a larger project experiences delay, it ought to cost more money to make up the time deficit. The cost growth index removes unique assignments of cost to enable comparisons. When this was done, we found that the ratio between final and initial costs is significantly higher for reimbursable contracts versus fixed price contracts. Higher cost growth in reimbursable contracts aligns with other industry research. Reimbursable contracts do not incentivize cost-control (Nkuah, 2006); rather they may incentivize cost growth (Wamuziri, 2013).

Schedule.

The average time required to complete a reimbursable project is greater than the time for a fixed-price project. This finding confirms Jaszkowiak's (2012) finding for other Afghan and Iraq US military construction projects. The observed schedule growth is expected because structurally, schedule and cost growth are strongly linked in reimbursable contracts. By law, schedules extensions are accompanied by an increase in funding (GSA, 1984). Based on this structural connection, we would expect contract modifications to be a mediating variable. Indeed, previous research has shown that contract changes are closely related to schedule performance in projects (Ibbs, 2012). While total number of scope modifications was not different between the contract types, reimbursable contracts had more schedule modifications than fixed contracts. Additionally, the number of days added to the contract was also higher for reimbursable contracts. Therefore, the results suggest that, rather than scope changes being the cause of schedule extensions, as Ibbs (2012) suggested, it may be some other mediating factor, or

possibly the contractor's lack of incentive to adhere to the schedule that begets more time extensions in reimbursable contracts.

Contract types also had a near-significantly p-value for differences in the awarded schedule growth index. The p-value was so close to 0.05 (unlike any other factor) that additional analysis was performed for the factor. A contingency table showed that schedule growth could be dependent on contract type. Reimbursable contracts had higher schedule growth than fixed contracts. This reflects similar behavior as discussed with final costs: contractors for reimbursable contracts may not be motivated to control schedule growth (Nkuah, 2006). FFP contractors are incentivized to minimize construction costs and schedule, which involves indirect costs as the project is delayed. CPFF contractors do not have these inhibitions for either cost or schedule. The construction agent reported that contractors would often divide their original bid by the number of days in the period of performance to establish a daily burn rate. Oftentimes, the daily burn rate was maintained or exceeded. But just as often, the planned schedule was not met, and the allocated funds were exhausted before the project was complete. Therefore, when more time was granted to the project, additional funding had to be granted to complete the same project (Schoenenberger, 2014). By design, CPFF projects have greater potential for schedule growth, and this research found that for this sample, on average they did exhibit more schedule growth.

Performance.

Fixed-price contracts underperformed compared to reimbursable contracts in design performance and the contract management of the project. The daily reports indicated that the majority of the reported design deficiencies were due to incomplete

design submissions to the government. The incomplete designs created a rework/resubmission cycle. The contractors would choose to work at risk on the projects (sometimes for months) beginning construction without final, approved designs in order to meet contractual performance obligations. Similarly, the contractors frequently worked at risk as they tried to comply with contract management tasks. Contractors would miss submission deadlines and would have difficulty correcting the deficiency. However, the daily reports did not indicate that project quality was directly affected as a result of contractors working at risk. Acceptable designs or contract submissions were eventually submitted. The tests suggest that contractors did not pay as close attention to contract and design documents on fixed price contracts. It is interesting that projects were able to continue successfully in spite of severely late design submissions and approvals. This may confirm previous research suggesting there are unnecessary steps in the government design-review process, or that some details of design are not critical to project completion and simpler criteria may still yield a successful project (Blomberg, et al., 2014).

Mentionable lack of results.

This study did not find a significant difference in quality performance between the two contract types. This contrasts with Jaszkowiak's (2012) work. Her survey of construction professionals found that a reimbursable project tended to yield better-quality projects. This research did not find any craftsmanship quality differences between fixed price and reimbursable projects. These conflicting results may be attributable to the source of data. Jaszkowiak assessed overall perceptions from the government construction management teams whereas this study's data consists of QA deficiency reports. This research did not analyze customer satisfaction of the project, which is a

large factor in determining the final quality of a project (Baccarini, 1999; Lim & Mohamed, 1999). Notwithstanding, this research suggests that heightened deficiencies or poor quality work should not be a unique subject of focus for either contract type.

Reimbursable contracts are used in Afghanistan by the US government because of the increased risk due to the security situation. As a result, it was expected that external environmental factors would be more prevalent on reimbursable contracts. The use of this contract type is justified because of the more austere or uncertain project environments. However, there was no significant difference in delays due to any of the external environmental factors. In fact, security incidents and other external environmental delays (e.g. local interference) were reported more often in fixed-price contracts, though not significantly. This result may suggest that risk assessments may not adequately assess the security situation for both reimbursable and fixed-price projects. Additionally, the term "high-risk" has a broad meaning. A project may have been high-risk simply due to being in a remote location or due to the security situation. Additionally, some accessible projects are classified as high-risk because of the undefined scope, or anticipation of many change orders as the end-user firmed up requirements (Schoenenberger, 2014). As the external environment was not a significant factor between contract types, these findings may also suggest that the high-risk projects are characterized more by vague project requirements than the environment.

Conclusion and Recommendations

Recommendation 1 – Find source of rework in Design Process.

As described in the discussion, the “failures” that most occurred with design performance and contract management were wasteful rework and missed deadlines. Previous research has shown that design rework problems can have a significant effect on the overall schedule of construction projects (Li & Taylor, 2014). Furthermore, Blomberg, et al. (2014) performed a case study on two near-identical projects to show that internal policies and procedures can be a significant cause of cost increases. Other research has shown that, in some cases, design review systems are often plagued by inefficient processes. However, oftentimes the realignment of tasks and priorities increases efficiency (Palaneeswaran, et al., 2014). Aside from being more aware of possible design performance problems in fixed-price contracts, it may help construction agents to perform lean analysis, or some kind of similar process improvement, of their audit systems to ensure that inefficient reviewing or unnecessary requirements are not the root-cause of rework for contract submittals.

Recommendation 2 – Scrutinize Tasks & Productivity in Reimbursable Projects.

For cost reimbursable projects, two metrics are critical to maintaining the schedule: a progress measurement system and a productivity index (Nkuah, 2006). In fixed-price contracts, individual line-items are not important to auditing the project. However, in reimbursable projects, the ultimate cost of the project is a sum of all individual costs – all of which require approval and review. Any task that finishes late will require additional labor (and possibly material) than originally planned will, as a result, increase the cost of the project. In order to minimize risk to the owner and remain

informed of the exact progress of the project, construction agents should consider using a system that measures incremental task progress and aids in the detailed inspection of small line-items (Nkuah, 2006).

Quality assurance engineers should also have the ability to measure the labor productivity for all project teams. After all, “the craft labor force is the major element that affects the cost and schedule of a cost reimbursable project.” (Nkuah, 2006) The primary metric for this is the productivity index, which is a ratio of the actual hours and the planned hours. There are specific methods by which a QA engineer may assess the productivity index for a contractor, and compare the metric to the original plan. When the index is above one, then the project costs are greater than the planned amounts. This helps the construction agent to forecast progress, as well as identify areas of the project to scrutinize and address with the contractor. Finally, to ease the process and reduce labor of inspection, the recommendation is to make the audit system simple and easy to understand and implement (Nkuah, 2006).

A much more common method of measuring progress is by using earned value forecasting. These methods have been shown to be applicable in post-project tracking. Wauters and Vanhoucke (2014) used a Monte Carlo simulation to forecast cost and schedule performance with the cost performance index (CPI) and schedule performance (SPI) index. Additionally, Kim and Reinschmidt (2011) developed a Bayesian framework which used historical SPI and CPI data to forecast project cost and schedule performance. Implementation of these methods may help construction agents accurately track and control cost and schedule growth before it reaches an unredeemable level.

Recommendation 3 – Consider all contract types to minimize costs to owner.

In a wartime construction environment, risk is a significant factor of concern for both construction agents and firms. Previous research has already shown that the perception of risk significantly affects both bidding behaviors and also ultimate behavior of the contractor in response to significant changes in costs of completing the requirements of the contract (Baron, 1972). In wartime environments, it is logical for a construction agent to employ reimbursable contracts because of the low-risk the contractor carries. According to Baron‘s results, reducing risk to contractors ought to inspire motivation to bid, which increases the likelihood of a construction agent accomplishing its mission. The increased risk in wartime environments demands a more conservative construction model and an increase in flexibility. Reimbursable contracts possess both of these attributes.

However, it may behoove wartime construction agents to consider other construction models in order to minimize costs and waste to government. One uncommon option for government construction is the incentive-based contract. Fixed price and reimbursable incentive contracts are increasing in popularity in the private sector because they are designed to reward good performance and penalize poor performance. No additional action is required on the part of the owner (Veld & A, 1989). Previous research has shown that contract type is not the only predictor of whether or not a contractor will accept project risk. Price is also a factor. Previous research has used utility theory and decision analysis to find breakpoints, for different levels of risk, where a contractor will accept lump-sum prices over a cost-plus contract (Carr, 1977). Applying this model to government contracts, or performing updated analysis in future research, may assist

construction agents in selecting the most advantageous contract type in order to balance the risk, cost, and schedule. Therefore, there are root causes and reasons that may lead to the predictive factors. While the significant problems are indeed predictive, they may only be symptoms of greater problems with the two contract types.

Limitations.

This study was limited to 25 projects, which limited the type of statistical tests that could be used to perform analysis. Only non-parametric tests could be used, and only those that are known to be compatible with small-sample size populations. Future research should obtain a larger sample group (perhaps from USACE) which will increase the number of analysis options. Another limitation was the depth of data retrieval from the daily reports. The combined length of the daily reports was approximately 20,000 pages. Therefore, only major deficiencies were analyzed. However, there were many other minor incidents recorded by the QA engineers. In-depth case study research on smaller groups of these projects may provide further insight into performance differences between contracts.

Concluding thoughts.

The purpose of this research is to provide construction agents, firms, and military leaders alike with information that will help curb waste and aid strategic decisions regarding future military construction and nation-building projects. All of these facts underline the rapidly changing environment that is wartime construction, which has a significant effect on the progress of a project. While the results imply that cost growth and schedule growth seen in reimbursable contracts is greater than those of fixed-price contracts, it would be irresponsible to assume that FFP contracts are more advantageous

for the government to use in a wartime environment. There were specific reasons, usually risk-oriented, that led the construction agent to use CPFF contracts, especially in the initial stages of the Afghanistan reconstruction. Arguably, the use of CPFF may have prevented default of contractors on more high-risk projects. Instead, the moral of this paper is that owners need to be aware that reimbursable objects are likely to have more cost and schedule growth. Owners and their agents need to take decisive steps as described in the recommendations to minimize the growth and to reduce the overall amount of waste.

IV. Discussion

Chapter Overview

This chapter contains additional content relevant to the thesis topic, but inappropriate for inclusion in the scholarly articles. The material on the methodology contains background on contingency tables and their operation which may be helpful to follow-on students. The further discussion contains more in-depth discussion on the results of Kendall's correlation test for scholarly Article 1. This information is most relevant to the sponsor, but may also be useful for other students who are looking establish discrete probability values for decision analysis use.

Methodology

The contingency tables will serve to answer the question of independence for cost or schedule. Restated, the research question essentially asks, "Which are the factors – if any – upon which cost and schedule are dependent?" Contingency tables use categorical variables to sort occurrences of incidents, and then create marginal probabilities (McClave, et al., 2011).

The input factors to be observed in the projects are considered categorical. (Example: Concrete Quality Problems present versus not present.) The response variable is ultimate schedule performance or cost performance (expressed as a "1" for positive performance, and "0" for negative performance), which has already been divided into qualitative categories. The response variable is the separation between FFP or CPFF projects. A two-way contingency table will be created using every input variable from Table 2. An example is shown in Table 16. Additionally, once the data is split in this

way, a probability table will be developed, which will look similar to Table 16, except it will contain probabilities that are calculated by dividing the original values by the total number of data points.

Table 15 – Contingency Table Example

	Response A	**Response B**	*Totals*
Input A	n_{11}	n_{12}	R_1
Input B	n_{21}	n_{22}	R_2
Totals	C_{c1}	C_{c2}	n

There are some basic requirements which must be met in order for the contingency table to be used. The projects are independent in nature, have *k* possible outcomes (or categories), and the probabilities of all *k* outcomes will subsequently add to 1. Contingency tables also require each cell to have a large sample size, which is n=5 (McClave, et al., 2011). The dataset meets this requirement for the given inputs. The dataset is representative of the entire population of projects for the program being researched. Therefore a random sample is not necessary. The data meet the requirements to perform a multinomial contingency table experiment.

The experiment involves two different kinds of hypothesis test: the Chi-square test and Fisher's Exact Test. The Chi-square test is for when all cells are greater than 5 in a 2x2 contingency table. The initial hypothesis will be there that projects which were behind or ahead of schedule are independent of a given input. The test is performed using the X^2 test statistic. To find this value, the probabilities which correspond to the original table are used to calculate an expected value for each cell, which are in turn used to

calculate X^2. After comparing the test statistic to the value of $X^2_{.05}$ we will determine independence or dependence on the input attribute.

This thesis exclusively used Fisher's exact test because all of the tables had at least one cell which did not satisfy the $n = 5$ condition. The initial and alternative hypothesis are the same for Fisher's test as the Chi-Square test. The primary difference is that Fisher's exact test uses a hypergeometric-binomial combined distribution. The test is an iterative method, which manipulates the given table from one extreme possibility to another and results in a cumulative probability value (see Equation 1) which predicts the likelihood of the contingency table distribution occurring comparing to other possible combinations which could come from the sample population. Much like a normal p-value calculation, the null hypothesis is rejected when the probability value is below 5%, indicating dependence.

Equation 1 – Fisher's Exact Test

$$\boldsymbol{p} = \frac{\binom{n_{11}+n_{12}}{n_{11}}\binom{n_{21}+n_{22}}{n_{21}}}{\binom{n}{n_{11}+n_{21}}} = \frac{(n_{11}+n_{12})!\,(n_{21}+n_{22})!\,(n_{11}+n_{21})!\,(n_{12}+n_{22})!}{n_{11}! * n_{12}! * n_{21}! * n_{22}! * n!}$$

For the second article, the Mann-Whitney test used to compare performance differences between reimbursable and fixed-price contracts (although one contingency table comparison was used). This test was employed because it is known for being more accurate when used in non-parametric situations (i.e. when distributions are not normally distributed). Different than an *f*-test it employs a ranking system by comparing each point of one dataset and observing how many points of the comparison population are below it. A score is assigned to that data point. The sum of all of the score is the rank for that

category. A test statistic is then calculated using the rank, the mean rank of that variable, and the standard distribution of the individual rankings. This test statistic is then applied to a normal distribution table to find a probability or *p*-value.

Additional Discussion of Results

The Appendix contains from additional results from the statistical software JMP®. Primarily, the distributions were not displayed. Therefore, to provide additional insight on how breakpoints were established for the contingency tables, the distributions are made available in the appendix.

Interestingly, quality problems with the building foundation were significantly correlated with many other deficiencies and external environmental issues. Most significantly, projects that possessed foundation problems were also very likely to possess project management ($r = 0.6365$, $p = 0.0001$) and contract management ($r = 0.373$, $p = 0.025$) problems as well .There was also association with increased safety deficiencies ($r = 0.4542$, $p = 0.006$), poor horizontal work ($r = 0.3985$, $p = 0.022$). The relationship with horizontal work is intuitive; both often involving concrete. But the relationship with safety deficiencies is vague. Although it interesting to note that, of the six projects sited to possess foundation problems, 5 were located in the Kabul region.

Many of the shop drawing and material submittal deficiencies were instances where the construction team deviated from the original design. Many times, the construction team declared the change technically acceptable and a retroactive design change was accepted by the government. While these deficiencies may have ultimately met the intent of the project, this issue suggests that there may be disagreement between

the design engineers' vision and the true capability of the construction team (whether it be material availability or level of skill possessed by the labor force). These unnecessary processes ultimately take attention away from the project by the staff, as well as the quality assurance engineers, who have a due diligence to ensure that the project is built according to the approved design. Time and effort could be saved if the construction team coordinated with design staff to ensure the project is designed in such as way that it may also be built in a wartime environment.

Electrical deficiencies were associated with an increase in contract modifications ($r = 0.41$, $p = 0.01$) and also correlated with poor material and submittal incident rate ($r = 0.36$, $p < 0.05$). The daily reports often cited electrical problems being the result of installing improper or unapproved material, and thus required rework. AFCEC also mentioned several instances where electrical work was the critical path line-item, and required FPOP extensions – which necessitate contract modifications. Additionally, being one of the more technical crafts of construction, the workers in a developing country like Afghanistan often did not initially possess the skills necessary to complete the work, which required training and additional time; another cause for a modification.

Nearly all of the crafts were correlated with safety deficiencies to some degree, but reportable safety incidents had some more unique relationships. Structural had the strongest relationship to deficiencies ($r = 0.50$, $p < 0.01$); it is noteworthy that falling and being struck by objects are among the most common types of construction accidents (OSHA, 2014). Safety incidents were also correlated to increase in external environmental issues besides security incidents ($r = 0.48$, $p < 0.01$) and also associated with increases in the awarded cost growth ($r = 0.40$, $p < 0.05$).

Structural deficiencies were strongly correlated to project management problems ($r = 0.56$, $p < 0.001$) and foundation deficiencies ($r = 0.49$, $p < 0.01$), as well as some other crafts. Aside from the foundation, the structural portion of the work must usually be completed before any further crafts can be begun. These results suggest that there may be a “bottle-neck” in the structural discipline which can more significantly affect the final cost of the project. It is also possible that larger, more costly, projects also have more complex structural work, and therefore garner more scrutiny or challenges in the structural discipline. There may also be a mediating relationship shown by the relationship between project management and design performance ($r = 0.32$, $p < 0.05$).

Oddly, mechanical problems correlated positively with project budget performance ($r = 0.43$, $p < 0.05$). Meaning that budget performance improved as mechanical deficiencies increased. Follow-up contingency tables tests were performed to see if this relationship could be explained. Mechanical showed to be very dependent on structural quality ($p < 0.05$) and interior finishing quality ($p < 0.01$). These factors did not explain the relationship to budget performance, but did confirm that interior finishing and structural design are critical to the successful installation of mechanical systems. It is possible that the correlation between budget performance was a coincidence of the data due to the smaller sample size and should be discarded.

V. Conclusion

Chapter Overview

This chapter provides a summary of the results and significance of the thesis. There will be further discussion of future research that was not included in the scholarly articles, a review of the research findings as found in the two scholarly articles, some discussion on the significance of the research, and final concluding thoughts.

Review of Findings

The two scholarly articles analyzed 25 AFCEC projects to search for answers to two research questions related to wartime construction projects, and their performance. The findings from the two articles provide excellent insight into wartime construction and also show the need for additional research on wartime construction projects, which will be discussed in a later section.

The first research question asked, “Which factors affect the success of wartime construction projects?” The results from the first article showed that allowed schedule growth can predict budget performance. Additionally, when the construction agent gives additional time for a contractor to complete a project, this may actually increase the likelihood that a contractor will be late. Moreover, project management issues can be predictive of schedule performance, and through interviews and background information on project managers may improve future project performance. Finally, weather, security, culture, and other external environmental factors were not predictive of budget or schedule performance.

The second question investigated how wartime project outcomes differ based on the contract type (fixed-price or reimbursable). The results showed that reimbursable contracts take longer to complete and cost more than fixed price contracts. Fixed price contracts are more often plagued by design performance and contract management problems. However, the study found that there was no significant difference in construction deficiency occurrences. Additionally, there was no different in security or external environmental delays, which may be insightful for future contracts, given that reimbursable contracts were used because of increased project risk factors.

Significance of Research

Wartime construction is an inherent activity in a nation-building effort, and it is likely that there will be a similar effort from the United States and coalition partners in future conflicts. It would be helpful for construction agents to manage a knowledge database which captures and distributes the lessons that can be learned from mistakes and successes of past wartime projects. However, if these lessons are not captured, the risk or repeating past mistakes will only be higher. This thesis addresses a small part of this knowledge base, and also serves to once again open discussion on the topic of wartime construction in the world of academia. It reminds construction agents that project management is a crucial function of a project to scrutinize. Additionally, budget auditing measures should be meticulously maintained by construction agents to control cost growth. Also, there are significant performance differences between fixed-price and reimbursable contracts, and there may be other suitable contract models – particularly with incentives – that would control cost and schedule growth in future projects. There

are many other opportunities for future research in wartime construction and continued knowledge-gathering is vital to the future success of all DoD construction agents.

Additional Future Research

This study focused on projects that were completely nation-building in purpose, which differed greatly from the conventional mission of AFCEC and USACE, which usually construct projects solely for US government use. Many of these government-used projects are still located outside of the United States; some are in war zones and some are not. A comparison of this program to government-used programs may reveal some key differences between how foreign, federal projects perform versus projects foreign projects that are designed for host-nation development. In the event that another long-term nation-building effort is attempted by the United States and its allies, this comparison data may be useful in further discerning unique challenges to executing nation-building projects in a contingency environment.

As shown by the literature review, one of the most common ways to search for primary causes of delay is by surveying construction professionals. This survey data is made stronger when compared with quantitative data. A survey could be developed to interview a mix of individuals who worked on this research program. AFCEC staff, quality assurance engineers, NTM-A staff, Prime Contractors, and even sub-contractors could be surveyed to find root causes of delays, quality problems, and cost overruns. Interviews could also be used, and combined with qualitative coding software, such as Atlas TI®. Many of these construction professionals are still tied to the program, but as the effort in Afghanistan comes to a close, they are moving to other jobs. Time is of the

essence to ensure that lessons from these subject matter experts can be captured in a useful way.

Part of the data collection for this effort included the extensive schedules that are produced for larger projects. There were also many updates for each schedule between the beginning and end of each project. For this research, only minimal data was pulled from the schedules. There remains many additional insights into schedule execution that could be useful for the government in future efforts. A more expansive study (perhaps with a group) would be the comparison of the scheduled work to be completed with the daily reports and quantity of work actually completed. This would provide detailed earned value data, which may sometimes be different than that of the contractor-supplied cost and schedule data – due to the optimistic presentation often given by contractors when presenting their progress.

Due to the vast amount of documentation that needed to be reviewed for the data-mining in this research, only major deficiencies were coded for the contingency table analysis. However, case-studies could be performed for each individual project, or a small group of projects, which would allow for more detailed coding and root-cause analysis. There are several large projects (~$100 Million) that would be excellent candidates for this type of research, due to the diverse collection of challenges experienced.

A regression model of a larger sample-size of Afghanistan projects could provide useful data comparison across AFCEC and USACE projects. It would allow for broader factors and differences to be analyzed for the entire country-building program. Additionally, comparison of the Afghanistan program to the Iraq program may also be

useful in order to include multiple nation-building efforts. Ultimately, this type of research would emphasize the analysis of project metadata, such as location, general size, contract execution method or agent, mission purpose, owner, year of construction, and other similar factors. This may provide high-level decision-makers key information when making decisions about how a large program should be managed.

Quantifying the external environment was a difficult task of this research, and there remains much research to be done on this issue. Originally, the research included external environmental factors in order find whether or not these issues were indicative of overall performance or craft performance problems. This research can draw no such inferences because there were no significant relationships. Weather was the only external environmental issue that directly correlated with any other factors, and these relationships were not easily explained. Regarding security: every craft – with the exception of mechanical – correlated with security incidents. There wasn’t any reasonable explanation for these correlations. A third scholarly article was begun to perform root-cause analysis on external environmental factors. Unfortunately, the researching student did not have enough time to perform the analysis for this article. Should a future student want to continue this effort, the data is readily available.

AFCEC also believes that the 365 POP, which is primarily end-user-driven, has a negative effect on the project schedule performance. Although, in this thesis, if a schedule extension was justified, a project was not necessarily considered behind, AFCEC believes that projects were thwarted by setting unrealistic schedules, and then inevitably forced to adjust. The effort required to reorganize and redistribute resources may have negatively affected a contractor when setting realistic schedules at the onset of

a project may not have had such a poor effect. Future research could compare NTM-A project to MILCON projects that were programmed by coalition customers. These MILCON projects did not require a strict 365 schedule. Rather they maintained more flexibility. Contractors for these projects rarely went over-schedule. It would be interesting to identify any performance differences between these types of projects.

This research may have unintentionally answered the question, “What effect does a quality assurance program have on a construction project.” AFCEC was very stringent regarding the use of a QA engineer on all sites, which often created additional complications and expenses for the NTM-A officials, due to the logistics of having a third-party contractor on-site to inspect all activities, and ensuring their personal safety. Conversely, USACE did not use QA engineers on many of their NTM-A projects and were also forced to terminate many projects for contractor default. (AFCEC only had one termination for default.) There was no research done in this thesis to compare performance of project that used QA engineers versus those that did not. However, the results of this research were dependent on the observations of the quality assurance engineers; and the logical results should validate that the QA engineers were adequately performing their duties and may have also been associated with positive performance of project. The correlation tests reflect strong relationships between deficiencies and the ultimate budget and schedule performance of the projects. Further research should be done to affirm whether or not quality assurance engineers actually reduce the risk in contingency construction projects, as this research suggests.

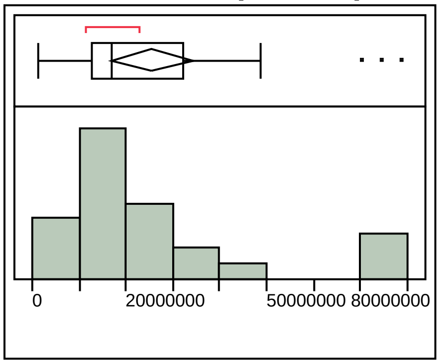
Summary

This research explored performance factors that predicted performance and found performance differences between contract types. The purpose of this research was to understand wartime construction as it differs from peacetime construction, and how AFCEC executes an innovative and unique construction program with an very low contractor default record. The research methodology used 25 AFCEC-Afganistan projects for an in-depth review of project schedules and schedule updates, invoicing and earned-value data, and thousands of daily project reports. The data were used to perform contingency table predictions, correlations, and pairwise median comparisons. This investigation shows that owner oversight may be the single most critical aspect to effectively controlling cost and schedule overruns in wartime projects. Additionally, it also shows that there are significant performance differences between reimbursable and fixed-price contracts in both cost and schedule, and virtually none in craft performance or delays from the external environment. Future recommendations are to ensure detailed cost controls, limit schedule extensions, reevaluate the design review process to eliminate wasted effort, develop detailed quality assurance programs that can track detailed progress levels, scrutinize and review all project managers, and consider incentive contracts to balance risk between owner and contractor. Overall, the analysis identifies ways to anticipate poor performance respond with improved methods to manage these wartime projects.

Appendix

Distributions used to determine breakpoints

Award Amount (AFCEC) 1



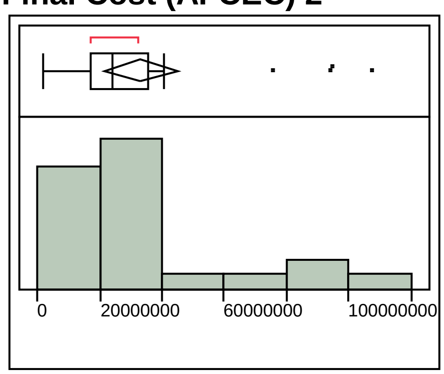
Quantiles

100.0%	maximum	7.88e+7
99.5%		7.88e+7
97.5%		7.88e+7
90.0%		7.2e+7
75.0%	quartile	3.23e+7
50.0%	median	1.7e+7
25.0%	quartile	1.27e+7
10.0%		5188022
2.5%		1201753
0.5%		1201753
0.0%	minimum	1201753

Summary Statistics

Mean	25504853
Std Dev	21372046
Std Err Mean	4274409.3
Upper 95% Mean	34326800
Lower 95% Mean	16682906
N	25

Final Cost (AFCEC) 2



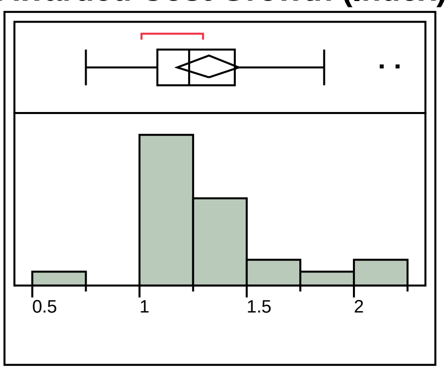
Quantiles

100.0%	maximum	1.07e+8
99.5%		1.07e+8
97.5%		1.07e+8
90.0%		9.42e+7
75.0%	quartile	3.56e+7
50.0%	median	2.39e+7
25.0%	quartile	1.7e+7
10.0%		5577743
2.5%		1552538
0.5%		1552538
0.0%	minimum	1552538

Summary Statistics

Mean	33189176
Std Dev	28652137
Std Err Mean	5730427.3
Upper 95% Mean	45016197
Lower 95% Mean	21362156
N	25

Awarded Cost Growth (Index) 3



Quantiles

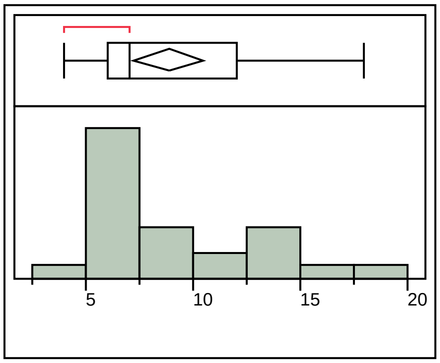
100.0%	maximum	2.20241
99.5%		2.20241
97.5%		2.20241
90.0%		1.97066
75.0%	quartile	1.44088
50.0%	median	1.22923
25.0%	quartile	1.08193
10.0%		1.00331
2.5%		0.74669
0.5%		0.74669
0.0%	minimum	0.74669

Summary Statistics

Mean	1.3214689
Std Dev	0.3477724
Std Err Mean	0.0695545
Upper 95% Mean	1.4650223
Lower 95% Mean	1.1779156

N	25

Number of Contract Modifications (AFCEC/DR) 5



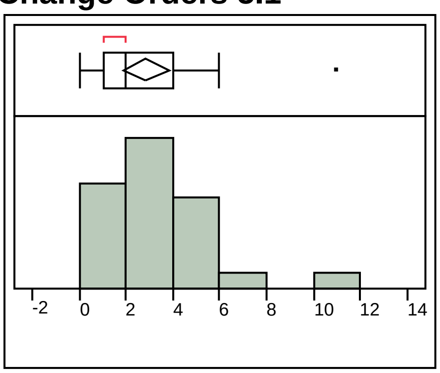
Quantiles

100.0%	maximum	18
99.5%		18
97.5%		18
90.0%		15.2
75.0%	quartile	12
50.0%	median	7
25.0%	quartile	6
10.0%		5
2.5%		4
0.5%		4
0.0%	minimum	4

Summary Statistics

Mean	8.88
Std Dev	3.9403892
Std Err Mean	0.7880778
Upper 95% Mean	10.506513
Lower 95% Mean	7.2534873
N	25

Change Orders 5.1



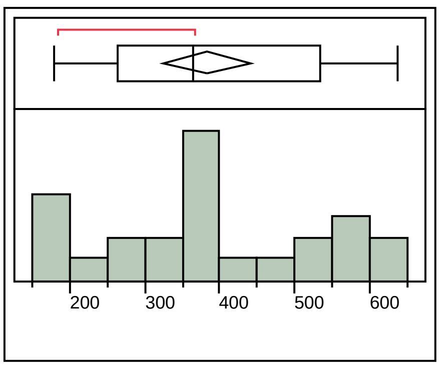
Quantiles

100.0%	maximum	11
99.5%		11
97.5%		11
90.0%		5.4
75.0%	quartile	4
50.0%	median	2
25.0%	quartile	1
10.0%		0.6
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	2.84
Std Dev	2.3572583
Std Err Mean	0.4714517
Upper 95% Mean	3.8130284
Lower 95% Mean	1.8669716
N	25

Initial Period of Performance (AFCEC/DR) 7



Quantiles

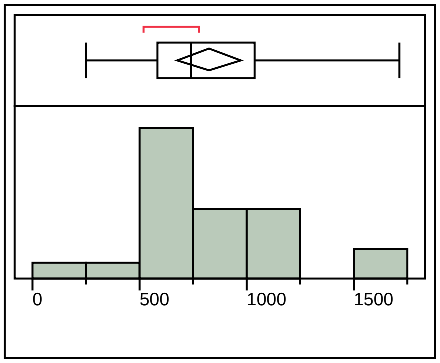
100.0%	maximum	637
99.5%		637
97.5%		637
90.0%		585.2
75.0%	quartile	535
50.0%	median	365
25.0%	quartile	262.5
10.0%		182.8
2.5%		178
0.5%		178
0.0%	minimum	178

Summary Statistics

Mean	382.76
Std Dev	142.09923
Std Err Mean	28.419845
Upper 95% Mean	441.41568
Lower 95% Mean	324.10432

N	25

Final Period of Performance (AFCEC/DR) 8



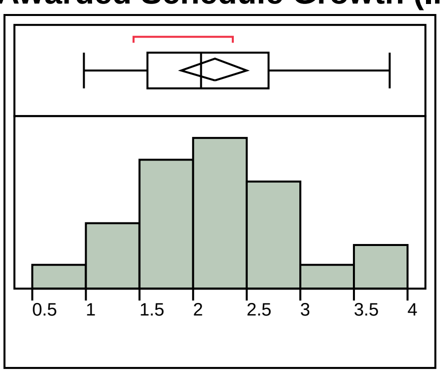
Quantiles

100.0%	maximum	1715
99.5%		1715
97.5%		1715
90.0%		1377.6
75.0%	quartile	1037
50.0%	median	741
25.0%	quartile	583
10.0%		447
2.5%		246
0.5%		246
0.0%	minimum	246

Summary Statistics

Mean	822.84
Std Dev	352.85676
Std Err Mean	70.571351
Upper 95% Mean	968.49211
Lower 95% Mean	677.18789
N	25

Awarded Schedule Growth (Index) 9



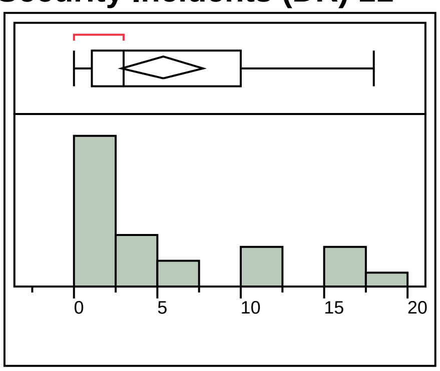
Quantiles

100.0%	maximum	3.84758
99.5%		3.84758
97.5%		3.84758
90.0%		3.36457
75.0%	quartile	2.69982
50.0%	median	2.07104
25.0%	quartile	1.57634
10.0%		1.20149
2.5%		0.98427
0.5%		0.98427
0.0%	minimum	0.98427

Summary Statistics

Mean	2.1983988
Std Dev	0.7528658
Std Err Mean	0.1505732
Upper 95% Mean	2.5091665
Lower 95% Mean	1.887631
N	25

Security Incidents (DR) 11



Quantiles

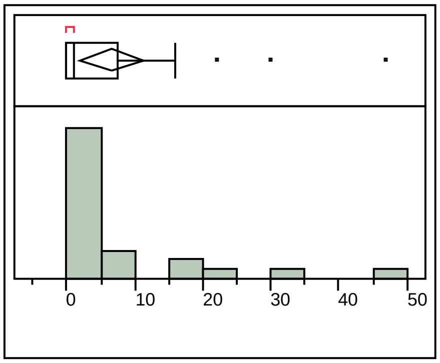
100.0%	maximum	18
99.5%		18
97.5%		18
90.0%		17
75.0%	quartile	10
50.0%	median	3
25.0%	quartile	1
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	5.32
Std Dev	5.9632206
Std Err Mean	1.1926441
Upper 95% Mean	7.7814965
Lower 95% Mean	2.8585035

N	25

Other external environmental issue 11.1



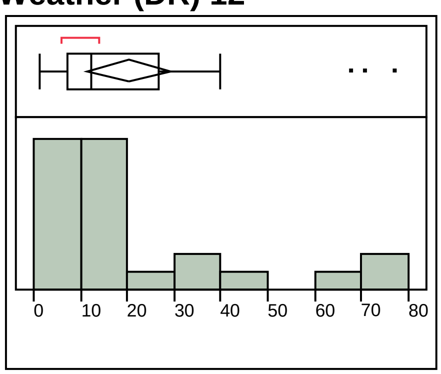
Quantiles

100.0%	maximum	47
99.5%		47
97.5%		47
90.0%		25.2
75.0%	quartile	7.5
50.0%	median	1
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	6.6
Std Dev	11.48187
Std Err Mean	2.296374
Upper 95% Mean	11.339483
Lower 95% Mean	1.8605171
N	25

Weather (DR) 12



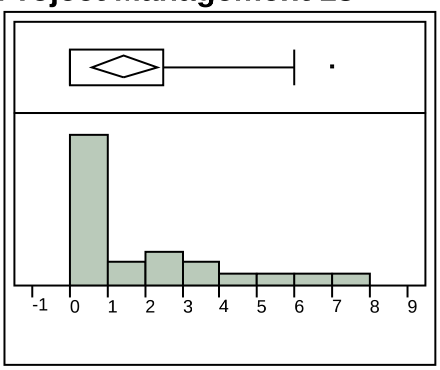
Quantiles

100.0%	maximum	77
99.5%		77
97.5%		77
90.0%		69.2
75.0%	quartile	26.5
50.0%	median	12
25.0%	quartile	7
10.0%		3.6
2.5%		1
0.5%		1
0.0%	minimum	1

Summary Statistics

Mean	20.32
Std Dev	21.653945
Std Err Mean	4.330789
Upper 95% Mean	29.258309
Lower 95% Mean	11.381691
N	25

Project Management 13



Quantiles

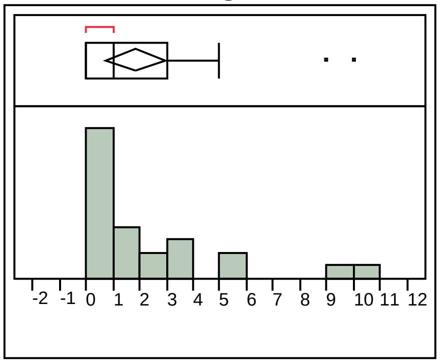
100.0%	maximum	7
99.5%		7
97.5%		7
90.0%		5.4
75.0%	quartile	2.5
50.0%	median	0
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	1.44
Std Dev	2.1031722
Std Err Mean	0.4206344
Upper 95% Mean	2.3081468
Lower 95% Mean	0.5718532

N	25

Contract Management 14



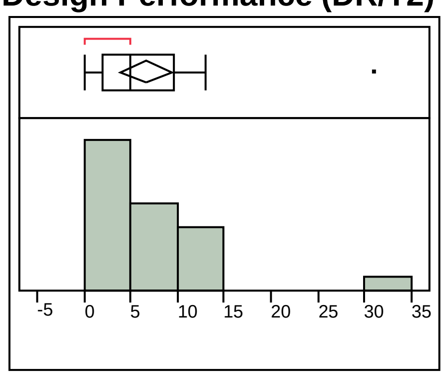
Quantiles

100.0%	maximum	10
99.5%		10
97.5%		10
90.0%		6.6
75.0%	quartile	3
50.0%	median	1
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	1.84
Std Dev	2.7790886
Std Err Mean	0.5558177
Upper 95% Mean	2.9871514
Lower 95% Mean	0.6928486
N	25

Design Performance (DR/T2) 15



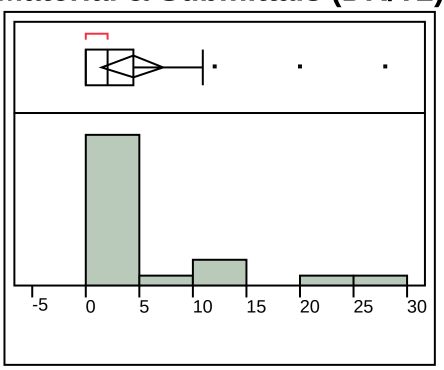
Quantiles

100.0%	maximum	31
99.5%		31
97.5%		31
90.0%		12.4
75.0%	quartile	9.5
50.0%	median	5
25.0%	quartile	2
10.0%		0.6
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	6.6
Std Dev	6.4678693
Std Err Mean	1.2935739
Upper 95% Mean	9.2698052
Lower 95% Mean	3.9301948
N	25

Material & Submittals (DR/T2) 16



Quantiles

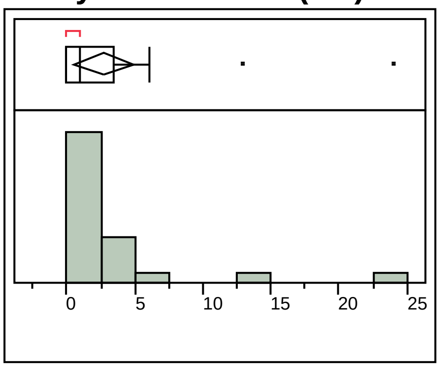
100.0%	maximum	28
99.5%		28
97.5%		28
90.0%		15.2
75.0%	quartile	4.5
50.0%	median	2
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	4.4
Std Dev	6.9880851
Std Err Mean	1.397617
Upper 95% Mean	7.2845398
Lower 95% Mean	1.5154602

N	25

Safety Deficiencies (DR) 17



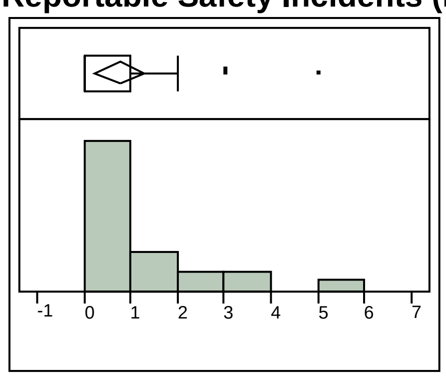
Quantiles

100.0%	maximum	24
99.5%		24
97.5%		24
90.0%		8.8
75.0%	quartile	3.5
50.0%	median	1
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	2.76
Std Dev	5.2700411
Std Err Mean	1.0540082
Upper 95% Mean	4.9353661
Lower 95% Mean	0.5846339
N	25

Reportable Safety Incidents (DR) 17.1



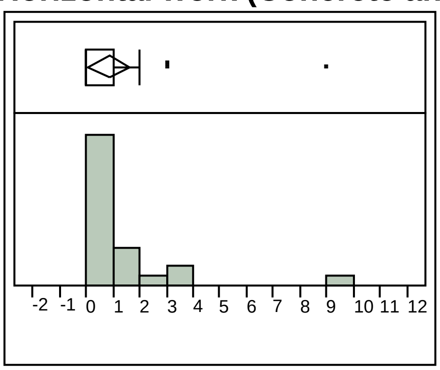
Quantiles

100.0%	maximum	5
99.5%		5
97.5%		5
90.0%		3
75.0%	quartile	1
50.0%	median	0
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	0.76
Std Dev	1.3
Std Err Mean	0.26
Upper 95% Mean	1.2966136
Lower 95% Mean	0.2233864
N	25

Horizontal work (Concrete and/or Asphalt) - (DR/T2) 18



Quantiles

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97.5%		9
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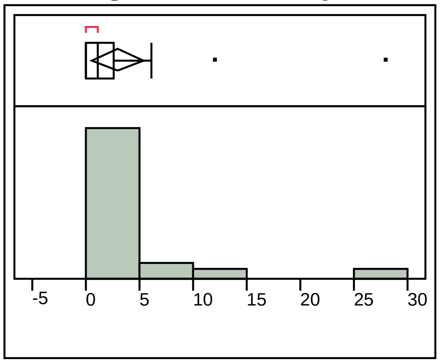
75.0%	quartile	1
50.0%	median	0
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	0.84
Std Dev	1.9295941
Std Err Mean	0.3859188
Upper 95% Mean	1.6364973
Lower 95% Mean	0.0435027

N	25

Building Foundation (Concrete, Rebar, Soils) - (DR/T2) 19



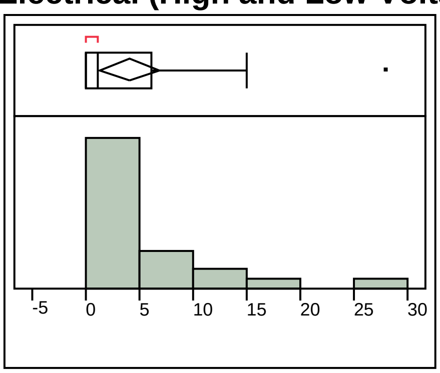
Quantiles

100.0%	maximum	28
99.5%		28
97.5%		28
90.0%		8.4
75.0%	quartile	2.5
50.0%	median	1
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	2.92
Std Dev	5.8375223
Std Err Mean	1.1675045
Upper 95% Mean	5.3296108
Lower 95% Mean	0.5103892
N	25

Electrical (High and Low Voltage, Comm Lines/Outlets) - (DR/T2) 20



Quantiles

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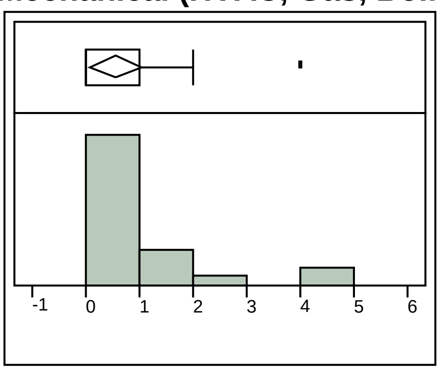
99.5%		28
97.5%		28
90.0%		14.4
75.0%	quartile	6
50.0%	median	1
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	4.08
Std Dev	6.8063696
Std Err Mean	1.3612739
Upper 95% Mean	6.8895313
Lower 95% Mean	1.2704687
N	25

Mechanical (HVAC, Gas, Boilers) - (DR/T2) 21



Quantiles

100.0%	maximum	4
99.5%		4
97.5%		4
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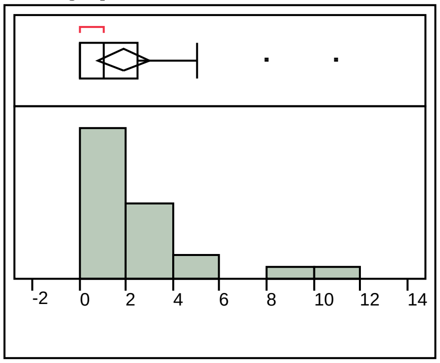
50.0%	median	0
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	0.56
Std Dev	1.1575837
Std Err Mean	0.2315167
Upper 95% Mean	1.0378271
Lower 95% Mean	0.0821729

N	25

Utility (Water, Sewer, and Storm) - (DR/T2) 22



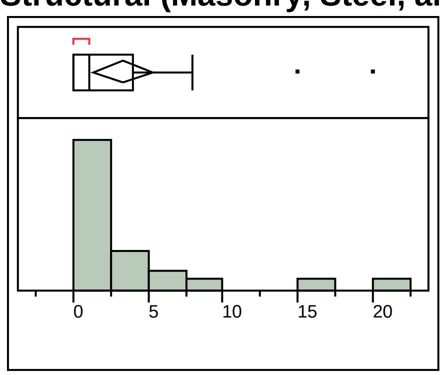
Quantiles

100.0%	maximum	11
99.5%		11
97.5%		11
90.0%		6.2
75.0%	quartile	2.5
50.0%	median	1
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	1.88
Std Dev	2.7282473
Std Err Mean	0.5456495
Upper 95% Mean	3.0061651
Lower 95% Mean	0.7538349
N	25

Structural (Masonry, Steel, and Wood) - (DR/T2) 23



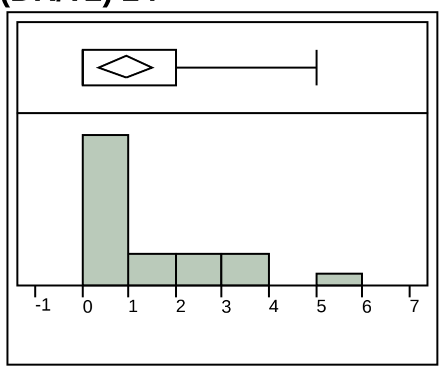
Quantiles

100.0%	maximum	20
99.5%		20
97.5%		20
90.0%		10.8
75.0%	quartile	4
50.0%	median	1
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	3.28
Std Dev	4.8863756
Std Err Mean	0.9772751
Upper 95% Mean	5.2969967
Lower 95% Mean	1.2630033
N	25

Interior Finishing (Doors, Tiles, Walls, Ceilings, Bathroom Fixtures, Paint) - (DR/T2) 24



Quantiles

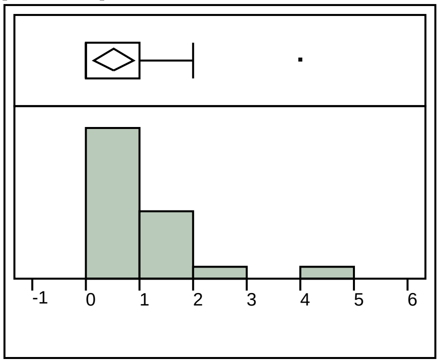
100.0%	maximum	5
99.5%		5
97.5%		5
90.0%		3
75.0%	quartile	2
50.0%	median	0
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	0.92
Std Dev	1.3820275
Std Err Mean	0.2764055
Upper 95% Mean	1.4904729

Lower 95% Mean	0.3495271
N	25

Exterior finishing (Windows, Exterior doors, Garage Doors, Fences) - (DR/T2) 25



Quantiles

100.0%	maximum	4
99.5%		4
97.5%		4
90.0%		1.4
75.0%	quartile	1
50.0%	median	0
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	0.52
Std Dev	0.9183318
Std Err Mean	0.1836664
Upper 95% Mean	0.8990687
Lower 95% Mean	0.1409313
N	25

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14. ABSTRACT

Using a dataset of 25 Afghan wartime projects, two questions were investigated: 1) What factors affect the success of construction projects; and 2) How do project outcomes differ based on the contract type? Current literature suggests that wartime projects may face the same cost and schedule factors as peacetime projects, with some notable additions. Project factors, health and safety compliance, quality of work, technical performance, work productivity, and external environmental factors were tested with contingency tables to determine dependency with schedule or cost performance. External environmental factors, including weather and wartime security, were not predictive of project performance. However, cost performance and schedule performance were significantly dependent on government-issued excusable delays. Moreover, project management deficiencies were predictive of poor schedule performance but not cost performance. Second with regards to contract type, performance differences between contract types were explored using Mann-Whitney tests. Reimbursable contracts were found to have significantly greater cost and schedule growth. Additionally, fixed price projects were found to have more problems with design performance and contract management. There was no significant difference in overall project quality. In conclusion, cost monitoring from the owner and scrutiny of project management is critical and increased technical performance monitoring is necessary.

15. SUBJECT TERMS
Contingency construction, wartime, contract types, key performance indicators, construction management

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